United States
Department of
Agriculture

Rural
Electrification
Administration

REA Bulletin 160-2

Mechanical Design Manual for Overhead Distribution Lines

FOREWORD

This revision* of REA Bulletin 160-2, Mechanical Design Manual for Overhead Distribution Lines, provides comprehensive information on the fundamentals of the design and staking of overhead rural electric distribution supply lines. Information is included for lines up to 34.5/19.9 kV and for conductor sizes up to 795 kcmil.

This manual is designed for use in training programs and as a general reference for the staff members of the rural electric systems of REA electrification borrowers. Therefore, the manual is written in a style suitable for beginning engineers, engineering technicians, stakers, construction inspectors and supervisors, and others associated with the design and construction of overhead line projects. Although the manual is written for this particular audience, it should also be useful to others involved in the design of overhead distribution lines.

The manual discusses the planning for design and staking of line projects; the application of the National Electrical Safety Code (NESC) to overhead rural lines; the REA system of unit construction and standard drawings; the selection of conductor design; the preparation of staking design guides; the staking of the line; the inspection of construction; and the stringing and sagging of conductors.

During the period of use of this particular edition of this design manual, it is contemplated the electric utility industry will be progressing in the transition from use of the U.S. customary system of units to the International System of Units (S.I.) metric system. This edition provides equations, methods, and data for designing with either system of units. Appendix A of the manual provides a guide for metric conversion.

The material in the manual which relates to the NESC is based on the 1981 edition of the NESC.

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Assistant Administrator - Electric

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Mechanical Design Manual for Overhead Distribution Lines
DESIGN, SYSTEM
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ENGINEERING AND OPERATIONS MANUAL

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REA BULLETIN 160-2

MECHANICAL DESIGN MANUAL

FOR

OVERHEAD DISTRIBUTION LINES

RURAL ELECTRIFICATION ADMINISTRATION
U.S. DEPARTMENT OF AGRICULTURE

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PART I
PREPARATION FOR AN OVERHEAD DISTRIBUTION LINE PROJECT

INTRODUCTION

The structure-by-structure detailed design of an overhead rural distribution line is usually accomplished in the field during the staking of the line. However, the engineering input to the design of the project begins long before the start of the staking. This part of this design manual reviews the engineering functions and the project planning which should take place in preparation for the staking of a project so that the staking may proceed in an efficient and timely manner.

The engineering input to an overhead line project can be divided into three principal categories; system planning, electrical design of system components, and the mechanical design of the line. This manual deals primarily with the last mentioned of these categories. However, there is an interaction between planning and design engineering in the preparation for staking of a project. Other REA bulletins provide assistance in planning studies and the electrical design of the system.

The preparation for the staking of most overhead distribution line projects actually begins with the system planning. The primary responsibility for the preparation of the system plan rests with the planning engineer. However, the plan requires input from the design engineer concerning the type of construction and the feasibility of line routes. Most major staking projects are the direct result of system planning and essentially every project is affected to some degree by the system plan. The plan also sets forth some of the basic criteria for the design of the line.

From this early interaction with the system planning, the design engineer proceeds to plan and prepare for the staking of the proposed line construction project.

For the line to be adequately and efficiently designed, the staking of the project must be well planned. The extent of the preparation and planning required will vary with the magnitude of the project and with the purpose of the line which is to be staked. The preparation for the staking project may involve any of the following elements:

- Long-range system planning;
- Construction work plans;
- Route selection;
- Coordination with other utilities;
- Permits for construction;
- Acquisition of rights-of-way;
- Selection of basic design criteria;
- Development and assembly of staking design guides;
- Equipping and staffing the staking crew;
- Staking reconnaissance of line route.

The planning required for staking a specific project must be tailored to the needs of that project.

This part of this design manual reviews briefly, how the above listed elements may be involved in the preparation and planning for staking the line project.

CHAPTER I-1
SYSTEM PLANNING

A. PURPOSE OF THE STAKING PROJECT

The preparation for staking the project may vary considerably with the purpose of the project. The project may be for a single short line, a major feeder line, or for a grouping of a number of lines to be included in a major construction contract.

The preparation will also vary with the type of line to be staked. The staking may be for construction of a new line, for modification of an existing line, or for combinations of these.

New lines may be short taps to serve new small consumers or heavy feeders to serve new large consumers or developments. They may be new feeders out of substations to relieve overloaded feeders, or tie-lines to improve reliability or to shift service area boundaries. Also, the purpose of the new line may be to replace existing lines, which must be removed due to obsolescence, road widening, or other causes.

Modifications of existing lines are usually made for the purpose of upgrading the capacity to meet increased loading requirements. Modifications may include the addition of phase conductors, increased conductor size, increased voltage levels, or combinations of these.

Some of these projects are the result of long-range system planning, while others may not have been considered in this planning. In either case, each project should be coordinated with the system plan.

B. COORDINATION WITH SYSTEM PLANNING

The planning for staking of most line construction projects begins with the system planning. The rural utility should have a current long-range plan which has been prepared for the entire system. This plan is a general development plan which includes logical routing for new or modified feeders, together with conductor sizes and voltage levels.

The system plan should also include a current construction work plan which has been based on the long-range plan. The work plan determines the timing for construction of new lines and modifications to existing lines. The work plan verifies the conductor sizes and verifies or provides a more definitive general route for the planned lines.

The input of the design engineer to the system planning might include any of the following:

- Feasibility review of proposed line routings to determine whether lines can be constructed along the proposed routes;
- Determination of what existing lines along the route are suitable for conversion or modification;
- Determination of factors along the route that might have unusual impact on the cost of construction;
- Determination of need and feasibility for joint construction with other utility lines along the route;
- Impact of changes of the NESC, local codes, and other regulations on the costs of construction.

The complete system plan identifies and provides some of the basic design criteria for most staking projects, including:

- Line voltage, and provisions needed for future voltage changes;
- Conductor ampacity or size;
- General routing of planned lines;
- Whether lines are to be overhead or underground construction.

The planning for staking of lines to supply new major loads which were not included in the system plan should include examination of the system plan. It should be determined if the line is a part of, or would logically be served from, a planned future line. If so, it may very well require changes in the timing, capacity, and routing of the planned line. The impact of the new load may be sufficient to require an update of the system plan for that portion of the system in the area of the new load.

It is wise to examine the system plan even when planning the staking of a short tap to serve a new, small consumer. Such loads will generally not have impact on the system plan. However, if the tap falls along the route of a planned future feeder, this should be considered in the design of the short tap.

CHAPTER I-2
ROUTE SELECTION AND ACQUISITION

A. ROUTE SELECTION

The next step in the planning for the staking is the determination of the final route of the line. In selecting the final route and choosing between possible alternatives, the following should be considered:

- Impact of length, terrain, angles, obstacles, and special crossings on the cost and strength of the line;
- Ease and cost of maintenance, including maintenance of tree trimming;
- Impact of trees; can they be cut, trimmed, or avoided;
- Impact of existing overhead and underground utilities paralleling or crossing the route; including electric, communications, gas, oil, water, sewerage, drainage, and irrigation;
- Availability, restrictions, or limitations on the use of public rights-of-way;
- Any plans for change, such as road widening;
- Availability of private rights-of-way;
- Impact of line on land use, environment, and on historical, archaeological, or biologically sensitive sites or areas.

The selected route should be identified and mapped in sufficient detail to permit the proceeding of coordination with other utilities, acquisition of rights-of-way, and application for necessary permits.

Along most probable line routes there will be certain points or areas which set, limit, or prohibit the setting of supporting structures. Such points or areas, therefore, are factors in determining location and alignment of structures and are commonly called control points. Control points include:

- Locations where it is necessary for the line to change direction;
- Man-made structures, facilities, and land use;
- Topographic and geographic land features.

The limitations imposed by the control points may be such as to:

- Define the general alignment of the route;
- Require special supporting structures;
- Prohibit use of the route.

Control points which will be critical to the definition of the final route should be identified. Such control points must be examined sufficiently to determine that structures can be designed and constructed at these points. Guidance concerning selection of control points is given in Part VI.

Data should also be collected concerning the topography and other characteristics of the route that might have impact on final decisions concerning the basic design criteria for the line. Topography may be considered as a factor in estimating or choosing a design ruling span as discussed in Part IV.

B. JOINT USE OF RIGHTS-OF-WAY

There are many reasons to avoid sharing of rights-of-way with other service utility facilities which might be located in close proximity to the proposed new line. However, there is increasing competition for remaining available rights-of-way and, in some cases, there may be little if any alternative. Close coordination is required with all other utilities with facilities along the new line route whether the joint use of the rights-of-way is for parallels or crossings of the facilities. The other utility facilities involved may include other electric power lines; telephone, cable television, or other communication circuits; water, gas, oil, sewer, drainage, or other pipelines.

Usually the utility involved in the new construction will be responsible for cost of non-betterment modifications, repair of construction damage, loss of revenue due to outages, installation of preventive maintenance devices, or systems such as cathodic protection, and other costs to the existing system resulting from the construction of the new facility. In some cases, it may be practical or necessary to construct joint use overhead lines with one of the other utilities. When alternatives are available, the costs of the shared rights-of-way construction should be considered when selecting the final route.

If the rights-of-way are shared with a public road or highway, the long-range planning for future road improvements should also be considered. If road widening is probable, it may be advisable to acquire rights-of-way outside the present limits of the road rights-of-way.

C. ACQUISITION OF RIGHTS-OF-WAY AND PERMITS

As soon as a final decision has been made on the selected route, the acquisition of rights-of-way should proceed. Priority should be given to those permits and agreements which are necessary to assure that the route can be used. These might include:

- Rights-of-way easements, purchases, or condemnations for private rights-of-way;

- Franchise or permits required for use of public rights-of-way;
- Environmental, land use, and other special permits required by jurisdictional authorities.

There needs to be close coordination between the rights-of-way and the design engineer. Rights-of-way easements, permits, or agreements should not include restrictions which might prohibit or severely restrict the design of the line. The rights-of-way person should have some general knowledge of the design requirements of the line and should seek the assistance of the design engineer when not certain. The design engineer usually provides permit drawings, coordinates engineering with other utilities, prepares preliminary design if needed, and provides other engineering assistance or guidance required in the acquisition of the rights-of-way.

CHAPTER I-3
PREPARATION OF STAKING AIDS

A. THE STAKING DESIGN GUIDE

The staking engineer completes the detailed design of an overhead rural distribution line while staking the line. The principal design aid used by the staker is the staking design guide. This guide is a collection of predesigned guides, tables, and other data or aids which either eliminates the need for, or assists in the preparation of, field computations for the design of the line. A properly prepared and well-organized staking guide will greatly facilitate the staking of the line.

Staking guides are based on the design criteria selected for the design of a line with specific numbers and sizes of conductor and type of supporting structures. A staking design guide is usually prepared so that it will be suitable for use anywhere on the system where such a design might be required.

Some time prior to the start of staking, it needs to be determined whether there is an existing staking design guide which is suitable for the proposed line. If not, the preparation or acquisition of a staking guide will be necessary.

B. REVIEW OF EXISTING DESIGN GUIDES

Most utilities have existing staking guides available for conductor sizes and types of supporting structures previously used on the system. However, these should be examined to determine whether the design criteria on which the data was based is currently valid and suitable for the proposed project.

Preparation of complete new design criteria and staking design guides, or a major updating of existing criteria and guides, is time consuming. Therefore, the determination of the need for new or revised data should be done as early as possible so that the data can be prepared or acquired by the time the staking is scheduled to start.

C. PREPARATION OF NEW DESIGN GUIDES

The determination of the basis for and the development of the design criteria, together with the preparation of the staking design guides for an overhead distribution line, constitutes the most significant part of the mechanical design effort. A major portion of this design manual deals with this effort. While the manual focuses primarily on the preparation of new data, the discussion can also be used to determine the validity of existing criteria and guides.

D. BASIS FOR THE DESIGN GUIDE

The preparation of the staking design guides is based on line design criteria which has been developed to meet the needs of the local utility and, at the same time, satisfy the requirements imposed on the utility by other authorities.

The basis for the design criteria includes:

- The National Electrical Safety Code (NESC) and local codes which are discussed in Part II of this design manual;
- REA standard construction drawings which are discussed in Part III of this design manual;
- Conductor design data and other criteria which are discussed in Part IV of this design manual.

The development of the design criteria is discussed in detail in Part IV. The preparation of staking design guides is discussed in Part V of this design manual.

CHAPTER I-4
PREPARATION FOR STAKING THE LINE

A. SCHEDULING THE STAKING

The scheduling of the staking for a line construction project may be very simple or can be a very intricate task involving complex scheduling methods.

When suitable existing staking design guides are available, the staking of a short tap can commence immediately prior to start of construction. On the other hand, for a major project, a determination should be made for the need of, and time required for, all of the prestaking functions which can affect the timing of the staking. Some of these functions are critical to the scheduling because they are sequential. Others can take place simultaneously. Some activities can overlap the start of the staking. The scheduling of these prestaking activities can be more complicated than the scheduling of the actual staking and construction of the project.

The determination of functions which need to be included in the schedule should be made as early as possible in the project and a schedule prepared. If time of completion is of essence, critical path scheduling may be useful.

B. REDUCING STAKING LEAD TIME

Some of the time required for prestaking activities can be reduced by anticipating future needs for these activities. Below are suggested ways for reducing the lead time required for start of line staking:

- Standardize as much as possible conductor sizes and types, and types of pole-top assemblies for supporting structures;
- Maintain current design staking guides for the line designs frequently used on the system;
- Review the guides when new editions of the NESC are published or when there are other occurrences which might invalidate portions of the data;
- When a new construction work plan is being prepared, make a new reconnaissance of probable general routing of proposed lines;
- Compare conductor sizes shown on the construction work plan with existing staking design guides; if the plan shows need for new staking data, start the preparation;
- Determine any need for joint construction with other utilities during the preparation of the construction work plan and start the coordination as soon as possible;
- Maintain a trained and properly equipped staking crew.

C. STAFFING THE STAKING CREW

Planning for the staffing of the staking operation should commence some time prior to the actual staking. The first determination to be made is whether the staking can be accomplished with the rural utility's own crews or whether outside assistance will be required. If outside assistance will be required, the decision should be made early. For the industry as a whole, staking has seasonal peaks and the outside consultants providing such services may be booked in advance for such periods.

The need for outside assistance may be determined by the following causes:

- Lack of an adequately trained staker on staff;
- Staking staff kept busy on day-to-day staking needs and unavailable for a major staking project;
- Staking project too large for staff and it is not economically feasible to develop added staff for a temporary staking peak.

Every rural utility should be able to assemble one adequately trained staking crew from its staff. If this is not the case, a major staking project may provide the opportunity to develop such a crew. The principal function of the outside service may be to train the utility staff crew.

D. EQUIPPING THE STAKING CREW

The planning for staking also includes assuring, in advance, that the tools necessary for staking will be available. This includes not only survey equipment, but also the design aids needed for the staking. The following checklist provides a reasonably complete list for a major staking project. Not all items will be required for every project.

STAKING CREW CHECKLIST

1. **Survey Equipment**
   - Suitable transportation
   - Distance measuring device for vehicle (optional)
   - Measuring wheels (optional)
   - Survey transit and tripod
   - Plumb-bobs
   - Hand levels and Abney hand level
   - Measuring chains and tapes
   - Chaining pins
   - Range poles and leveling rod
   - Insulated measuring stick for measuring clearances and sags of energized conductors
   - Stopwatch
   - Thermometer
   - Binoculars
   - Two-way portable radios
   - Hammer for driving stakes
   - Saws, axes, machetes, etc., for clearing brush
   - First aid and snake bite kits
   - Water jugs
2. **Staking Materials**
   - Stakes
   - Steel pins for permanent reference points
   - Marking lath
   - Marking ribbon
   - Marking crayons or pens
   - Staking sheet forms
3. **Design Aids**
   - Current NESC
   - REA design manual
   - Staking design guide for project
   - REA standard construction drawings
   - Utility design standards
   - System map of work area
   - Pre-staking reconnaissance notes
   - List of right-of-way restrictions
   - Calculator
   - Staking sheets for existing lines*
   - NESC edition used for staking existing lines*
   - Staking design guides used for existing lines*

   *These are useful, if available.

E. PRE-STAKING COORDINATION RECONNAISSANCE

The last pre-staking activity should include a final reconnaissance of the line by the principal persons who have been responsible for the pre-staking activities and those who will be responsible for the staking. As a minimum, responsible persons should include:

- The staker;
- The rights-of-way person;
- The staff engineer or persons responsible for final selection of the line route and design criteria.

The prime purpose of the reconnaissance is to communicate to the staker any special considerations concerning the design and routing of the line.

A list of rights-of-way restrictions or preferences of the land owners or public authorities should be provided and discussed.

A list of any special design instructions related to predetermined control points, etc., should be provided and discussed.

Any changes to the above lists and any new instructions should be recorded and formalized as the "pre-staking reconnaissance notes" and copies provided for use during the staking of the line.

PART II
THE NATIONAL ELECTRICAL SAFETY CODE AS A BASIS FOR DISTRIBUTION LINE DESIGN

INTRODUCTION

It is essential for those responsible for the design, construction, operation, and safety of electric power lines to be knowledgeable of the requirements of the National Electrical Safety Code (NESC). While this code is prepared as a safety standard, rather than a design standard, it has been commonly utilized as a basis for the design of electric power lines.

Part 2 of the NESC covers the safety rules for the installation and maintenance of overhead electric supply and communication lines. It is, therefore, the part of most interest to those involved with rural distribution systems. The 1977 edition of the NESC contained the most significant updating of Part 2 in over 50 years. New rules were added and many old rules were revised. The 1981 edition has continued this updating. It is, therefore, necessary to be familiar with the current rules of the NESC.

The NESC is written in typical legal code language which is not always easy to read. The code is complicated because it covers the rules for communication lines and electric power lines of all voltages. The purpose of this part of this design manual is to assist those associated with rural distribution systems to better understand those NESC rules which are most often encountered in the design of overhead distribution lines. This part of this design manual does not replace the current edition of the NESC. Some emphasis is given to those rules which have changed in recent editions of the NESC. So far as practical, the rules are discussed in the same order as they are found in the NESC.

CHAPTER II-1
AN INTRODUCTION TO THE NESC

A. SCOPE OF THE NESC

The National Electrical Safety Code is a voluntary safety standard approved as American National Standard ANSI C2 by the American National Standards Institute (ANSI).

The NESC covers basic provisions for safeguarding persons during the installation, operation, or maintenance of conductors and equipment in electric supply stations, and overhead and underground electric supply and communication lines. It also includes work rules for the construction, maintenance, and operation of electric supply and communication lines and equipment.

The NESC is applicable to the systems and equipment under the control of qualified persons operated by utilities or similar establishments.

In its entirety, the NESC consists of three introductory sections and four major parts as follows:

- **Sections 1, 2, 9** — Cover general rules, definitions, and grounding methods applicable to the other parts;
- **Part 1** — Covers the rules for the installation of electric supply stations and equipment;
- **Part 2** — Covers the safety rules for installation and maintenance of overhead electric supply and communication lines;
- **Part 3** — Covers the safety rules for underground electric supply and communication lines;
- **Part 4** — Covers the rules for operation of electric supply and communication lines and equipment.

B. PREPARATION OF THE NESC

The responsibility for the content of the NESC rests with the ANSI C2 Committee which operates under the administrative secretariat of the Institute of Electrical and Electronics Engineers (IEEE).

As secretariat, IEEE is responsible for the administrative management and technical direc-

tion of the ANSI C2 Committee and also publishes the approved NESC.

The ANSI C2 Committee is a semi-autonomous body authorized and operating under the procedures of ANSI to review and vote on the proposed NESC revisions. ANSI does not initiate or write standards, but provides the means by which national standards can be developed and approved. To obtain approval as an ANSI standard, the Committee must assure that all parties with a substantial interest in the NESC have had an opportunity to participate or comment on the proposed revisions, and that comments and negative positions have been considered and resolved to the satisfaction of ANSI.

The ANSI C2 Committee consists of members representing 24 organizations which are leaders in design, construction, maintenance, safety, regulation, and manufacturing for the electric power and communication industries. The Rural Electrification Administration (REA) is one of these member organizations.

In addition to the main ANSI C2 Committee, there are a number of subcommittees which are assigned responsibilities for parts of the code, categories of rules, or other functions of the NESC. The subcommittees are the working groups which, within their assigned categories, review comments and suggestions for improvements to the code and draft the proposed new rules or rule changes for submission to the main committee for consensus approval.

C. INTERPRETATIONS OF THE NESC

The ANSI C2 Committee also maintains an Interpretations Subcommittee which prepares replies to requests for interpretations of the rules contained in the code. Instructions for making requests are contained in the Foreword of the code.

The Interpretations Subcommittee has no authority to make code rules. Its purpose is to provide assistance in interpreting the intent of the rules as approved and published. The subcommittee members must reach a consensus before issuing an interpretation.

D. STATE AND LOCAL SAFETY CODES

Neither IEEE nor ANSI have any legal authority to enforce the code; therefore, the code sets forth a voluntary safety standard. However, many Federal, state, and other local jurisdictional administrative authorities utilize the NESC in the development of their own legal safety code. It may be adopted in part or in its entirety, unchanged, or modified as required to meet the needs of the administrative authority. Modifications, if any, are almost universally more restrictive, rather than less restrictive than the NESC.

The utility must conform to the legal safety code of the administrative authority which has legal jurisdiction over the utility.

In most states, a commission has been granted the legal authority to adopt and administer a state electrical safety code. In many cases, this commission also has the authority to regulate electric utilities. The legal process and time required for adopting or revising a code varies considerably from state to state.

There are several states which have never adopted a state safety code. In these states, the NESC essentially becomes a common law code by the judicial process.

In some states, cooperative and municipal systems are exempt from the code administrative authority of the state commission. In such states, it is advisable for the cooperatives to conform to the state code as well as the NESC.

E. REA PRACTICE CONCERNING THE NESC

REA Bulletin 40-6, Construction Methods and Purchase of Materials and Equipment, indicates that it is the responsibility of each borrower to determine the methods of construction best suited to its needs. However, from the viewpoint of protecting the security interests of the Government's loans, REA is properly concerned that the lines bearing on the security for loans are adequately constructed and incorporate reasonable safety provisions. In this sense, REA does require conformance with the NESC as one of the means of assuring adequate quality construction.

REA Bulletin 40-7, National Electrical Safety Code, states REA policy concerning use of the NESC. This bulletin requires borrowers to construct their lines in compliance with the current NESC, except where local codes and REA bulletins or directives are more restrictive.

REA does not purport to be an administrative authority for the NESC, does not make safety rules for the borrower's distribution lines, and

does not provide interpretations of the NESC. It is the responsibility of the borrower or the borrower's engineer to apply the requirements of the NESC to the design and construction of the system, to determine if there are applicable local jurisdictional authority codes, and to obtain interpretations of these codes when necessary. REA does make use of the NESC in preparation of bulletins such as this design manual, standard construction drawings, and other construction aids for use by the borrowers.

F. SYSTEM DESIGN GUIDES

NESC and state codes are safety standards, not design guides. Safety standards, such as the NESC and state safety code rules, are defined minimum requirements. Utility systems must meet or exceed these standards. In some cases, these standards will be inadequate for local conditions. Also, these standards do not provide tolerances for human error in staking, construction, or maintenance.

System design guides, are standards developed for a specific utility, based on experience, which assure that their supply lines will equal or exceed safety code requirements and provide adequate strength, clearances, and reliability for local conditions in the area served. Although the NESC and state safety codes are not design guides, they do provide a basis for the development of system design guides.

REA does not attempt to establish design guides to meet the needs of individual REA-financed distribution systems. It is the responsibility of the owner or the owner's engineer to determine the specific needs and to establish design guides appropriate for the local conditions. This design manual does provide some guidance in the determination of where design guides and tolerances may be needed.

CHAPTER II-2
INTRODUCTORY RULES OF THE NESC

A. NESC SECTION I - INTRODUCTION

Section 1 of the NESC is the Introduction to the National Electrical Safety Code. This section includes the purpose, scope, general rules, application rules, waiver rules, and intent of the NESC.

Prior to 1981 each part of the code contained its own introductory rules. The 1981 NESC moved those introductory rules common to all parts to the new Section 1.

These introductory rules are often overlooked or passed over lightly, yet they are very important rules of the NESC. They set the theme of the code and provide the basis for all of the specific rules of the NESC. When a situation or condition is encountered where no specific rule exists to cover a particular safety problem, the intent of these introductory rules must be applied to the problem.

B. THE PURPOSE AND GENERAL RULES (NESC RULES 010. AND 012.)

The Purpose and General Rules of the NESC found in Section 1 need to be examined together.

- Rule 010. Purpose, states:

> The purpose of these rules is the practical safeguarding of persons during the installation, operation, or maintenance of electric supply and communication lines and their associated equipment. They contain minimum provisions considered necessary for the safety of employees and the public. They are not intended as a design specification or an instruction manual.

- Rule 012. General Rules, states:

> All electric supply and communication lines and equipment shall be designed, constructed, and maintained to meet the requirements of these rules. For all particulars not specified in these rules, construction and maintenance should be done in accordance with accepted good practice for the given local conditions.

These two rules place the responsibility for providing practical safeguards on the utility which constructs, owns, and operates overhead electric supply lines. It is the responsibility of the utility to design, construct, and maintain the lines in a manner to provide practical safeguards both for its own employees and for the general public during the installation, operation, and maintenance of the lines.

The rules of the NESC provide practical safeguards for stated specific conditions. Many of these conditions relate to the use of the space under and adjacent to the lines. The utility is, therefore, responsible for determining the probable uses of these spaces in order to apply the proper NESC rule. Other rules are based on specific conditions or limiting conditions such as conductor temperature, conductor loading, and span lengths. Therefore, it is the responsibility of the utility to determine if the local conditions conform to those upon which the NESC rules are based.

Where the local use of space or other local conditions are such that no applicable NESC rule exists, the utility is responsible for the determination and provision of practical safeguards for these local conditions.

The rules also indicate that the safeguards should be practical. While safeguards must be provided for the public, it must also be recognized that it is the electric power consuming public which pays for the cost of safety. The use of the term "practical safeguarding" implies that there is some practical limit to the cost of safety which the consuming public should be required to pay.

These rules indicate that when practical safeguards are not covered by specific NESC rules, construction and maintenance should be done in accordance with accepted good practice for the given local condition.

Discussions and interpretations issued by the ANSI C2 Committee can also be helpful in determining when it is necessary to modify NESC rules in order to provide practical safeguards. These sources suggest that the NESC rules apply to the ordinary and repeated uses of the space under and adjacent to the lines and that it is not practical to provide additional safeguarding to extraordinary uses with low probability of occurrence. Two useful references are the National Electrical Safety Code Interpretations, 1961-1977 and the National Electrical Safety Code Interpretations, 1978-1980. While these references are out of date in regard to some specific rules of the current NESC, they do provide some good insight into the basis of the rules.

C. THE APPLICATION RULES (NESC RULE 013.)

Rule 013. of Section 1 provides the basic rules for how the specific rules of the NESC shall apply to both new and existing lines.

Rule 013.A. indicates that the rules of the current edition of the NESC shall apply to new installations and extensions of lines.

Rule 013.B. covers the application of the rules to existing lines, and reads as follows:

1. Existing installations, including maintenance replacements, which comply with prior editions of the code need not be modified to comply with these rules except as may be required for safety reasons by the administrative authority.
2. Where conductors or equipment are added, altered, or replaced on an existing structure, the structure or the facilities on the structure need not be modified or replaced if the resulting installation will be in compliance with the rules which were in effect at the time of the original installation.

Further, Rule 202 requires that "when a structure is replaced, the arrangement of equipment shall conform to the current edition of Rule 238C." Rule 238C applies to vertical clearance between communication equipment and span wires or brackets carrying luminaires or trolley conductors.

From Rules 013 and 202, the conclusion may logically be drawn that structures which are replaced for maintenance purposes need only comply with the code in effect at the time of the original installation. This point may be clarified by interpretation or possibly addressed in the next code edition. At the present time, it should be recognized that it is desirable, but often impractical, to bring each item of an existing installation into compliance with new code requirements when a structure is being replaced. The replacement of structures provides an opportunity to gradually bring existing lines into compliance with new code requirements. Insofar as practical to do so, this is considered good policy.

CHAPTER II-3
GENERAL DISCUSSION OF CLEARANCE RULES

A. NESC SECTION 23 - CLEARANCE RULES

The clearance requirements of the NESC are covered under Section 23 of the code. This chapter discusses certain aspects of clearance rules which are common to all clearance requirements covered under Section 23.

The clearance rules discussed in this design manual are limited to those pertinent to the design of overhead distribution lines supporting bare primary and secondary circuit conductors, single conductor covered service conductors, and multiplex service cables included on the REA List of Materials. NESC clearance tables included herein have been simplified by limiting the data to that commonly required for such construction.

The clearance values included in this part of the design manual do not include any design or construction tolerances. These NESC clearances are the minimum values which must be equaled or exceeded after the line is constructed and is in operation.

B. BASIC CLEARANCE REQUIREMENTS

Every code clearance requirement includes as a minimum a basic clearance requirement. These basic clearances vary in magnitude depending on the voltage range of the conductor, the nature of any covering on the conductor, and the use of the clearance space between the conductor and the object for which the clearance is being provided.

In Section 23 of the code, the basic clearances for the different clearance situations or categories are shown in table form. The basic clearances given in the tables may be qualified by the code rule which introduces the table and may be further qualified or modified by footnotes to the table.

C. ADDITIONAL CLEARANCE REQUIREMENTS

In many cases the basic clearance requirement is subject to one or more additional clearances. The additional clearances are most commonly for conditions of conductor voltage, conductor temperature, conductor loading, and conductor span lengths in excess of limitations imposed on the basic clearance requirements. These clearance additions are usually incremental and a function of the magnitude of the excess. These increases are cumulative where more than one apply.

The basic clearances are generally identified as being either vertical or horizontal clearances and the applicable additional clearances are arithmetically added in the same direction.

D. CONDUCTOR VOLTAGES

As used in NESC clearance rules, the voltage of a single-phase or multi-phase, alternating current circuit of the type commonly used on rural distribution systems is, unless otherwise indicated, the nominal effective voltage between any conductor of the circuit and ground.

The line-to-ground voltage of an effectively grounded circuit means the highest effective voltage between any conductor and ground except where indicated elsewhere. For circuits not effectively grounded, the line-to-ground voltage means the highest effective voltage between any two conductors of the circuit.

Grounded neutral single-phase and multiphase distribution circuits constructed in conformance with REA bulletins and construction drawings, generally meet the requirements for effectively grounded circuits. Therefore, for a 24.9/14.4 kV grounded wye circuit, the proper voltage to use for phase conductor-to-ground clearances is 14.4 kV, and for phase-to-phase clearances 24.9 kV is the proper voltage to use.

The voltage between two conductors of two different effectively grounded circuits is the vector difference of the line-to-ground voltages of the two conductors, except that if the two conductors are in-phase, the voltage shall not be less than the line-to-ground voltage of the higher voltage circuit. If there is a phase shift of 60 degrees between the two circuits, there is a possibility that the voltage can be as high as the sum of the two line-to-ground voltages involved.

Thus, the maximum possible conductor-to-conductor voltage between a 34.5/19.9 kV circuit and a 12.5/7.2 kV circuit is 19.9 + 7.2 kV or 27.1 kV and the minimum conductor-to-conductor voltage is 19.9 kV. The maximum possible voltage should be used unless the phase shift between the two circuits is positively known and will not change in the future.

E. VOLTAGE CLASSES

Clearance requirements are, in part, a function of conductor voltage. The clearance must increase as the voltage of the conductor in-

creases. For voltages common to distribution systems, the NESC simplifies the determination of clearance change due to voltage change by grouping the clearance requirements by voltage class. Each voltage class covers a range of voltages. Thus, for distribution voltages, the voltage increase is included in the basic clearance requirement for the specific voltage class.

F. BASIC CLEARANCE CONDITIONS

The basic clearance conditions and limitations for distribution voltage class circuits are, with few exceptions, the same for all clearance rules. These conditions and limitations are as follows:

1. Conductor Temperature

The clearance requirement is based on a normal conductor temperature of 15°C [60°F], no wind, with final unloaded sag in the conductor. This condition was changed in the 1977 NESC. Prior to 1977 the temperature was the ambient air temperature. It is now the conductor operating temperature.

2. Basic Span Length

The basic clearance is for span lengths not greater than those listed in Table II-1.

TABLE II-1
BASIC SPAN LENGTHS
(Adapted from NESC Rule 232A2)

NESC Loading District	Span Lengths[1] meters	feet
Heavy	53.3	(175)
Medium	76.2	(250)
Light	106.7	(350)

[1]The basic span is reduced for small three-strand conductors, each wire of which is 2.3 mm or less in diameter (approximately No. 12 wire). Conductors of this size are no longer included in REA Bulletin 43-5, List of Materials.

G. ADDITIONAL CLEARANCE RULES

For distribution lines, the additional clearances which are added to the basic clearance requirements are covered under the "sag increase rules."

The sag increase rules applicable to distribution lines consist of the following:

- Incremental increase rules, which cover the methods of increasing the basic clearances when the span length exceeds the basic span length:
- Incremental increase limit rules;
- Adjustments to additional clearance when minimum clearance is not at mid-span;
- High conductor operating temperature rules, which cover the methods of increasing basic clearances when the conductor operates above 50°C [120°F].

H. INCREMENTAL INCREASE RULES

The incremental increase rules apply to spans longer than the basic span length when the conductor is at the basic normal temperature of 15°C [60°F]. The general incremental increase rules apply to all crossings except crossings over railroad tracks and crossings over conductors of other circuits not carried on the same supports.

- **General Incremental Increase Rules**

NESC Rules 232B2c (1) and 234F2c can be modified to read as follows:

Where supply lines are designed to operate at or below a conductor temperature of 50°C [120°F] and the spans are longer than the limits specified for the basic span, the clearance at midspan shall be increased by a ratio factor of 0.01 times the excess of span length over the basic span limit.

The modification from the NESC rule is the use of a ratio factor which permits the rule to be equally usable with the metric system of units.

- **Example Problem**

Calculate the midspan clearance increase for a span of 103.3 m (339 feet) in the heavy loading district where the basic span limit is 53.3 m (175 feet).

$$C_x = F_c (S_x - S_b) \qquad \text{EQ II-3A}$$

Where:

S_x = Length of span
C_x = Midspan clearance increase for Span S_x
S_b = Basic span limit
F_c = Increase ratio factor

- **SI Metric Example**

$C_x = 0.01\ (103.3 - 53.3)$ m
$C_x = 0.5$ m

- **U.S. Customary Example**

$C_x = 0.01\ (339 - 175)$ ft.
$C_x = 1.64$ ft.

- **Railroad and Conductor Crossing Incremental Increase Rules**

NESC Rules 232Bc (2) and 233A2b (3) which cover railroad track and crossings of conductors over other circuits not carried by the same supports can be restated to read the same as the general rule above except that the increase ratio factor must be modified as given in Table II-2.

TABLE II-2

CLEARANCE INCREASE RATIO FACTOR

Loading District	Clearance Increase Ratio Factor	
	Large Conductors	Small Conductors[1]
Heavy and Medium	0.015	0.03
Light	0.01	0.015

[1]Conductors smaller than No. 4 AWG copper and No. 2 AWG aluminum are classified as small conductors.

I. LIMITS TO INCREMENTAL INCREASE RULES

The limitations to the incremental clearance increase rules were changed by the 1977 NESC.

The old "maximum sag increase" limit has been eliminated. The old rule determined a span length beyond which the incremental increase no longer had to be added. This change means that for longer spans, the total clearance requirements may be greater than under the previous rules.

While a new limit rule, NESC Rule 232B2c (3), has been substituted, it will be unusual to find a case where the new limit will affect distribution design. If the new limit rule is ignored, any error in the calculated clearance will be conservative.

J. ADJUSTMENTS TO ADDITIONAL CLEARANCE

Where the minimum clearance is not at midspan, the additional clearances may be reduced by multiplying the additional midspan increase by the factors given in Table II-3.

When using an electronic calculator, it may be simpler to calculate the factor than to interpolate. The equation follows:

$$F_r = 1 - 0.0004\,(50 - x)^2 \qquad \text{EQ II-3B}$$

Where:
F_r = Reduction Factor
x = distance from the nearer support as a percentage of the span length.

The factor can be calculated directly by the following equation:

$$F_r = 1 - \left(\frac{S-2z}{S}\right)^2 \qquad \text{EQ II-3C}$$

Where:
S = Span length
z = distance from the nearer support

- **SI Metric Example:**

Find the net sag increase (C_n) at 10.33 m from a support.

Where:
S = 103.3 m
z = 10.33 m (10% of S)
C_x = 0.5 m (increase at midspan)
$F_r = 1 - \left(\frac{103.3 - 2 \times 10.33}{103.3}\right)^2$
$F_r = 1 - 0.64$
$F_r = .36$
$C_n = F_r \times C_x$
$C_n = .36 \times 0.5$
$C_n = .18$ m (net sag increase at 10.3 m from nearer support)

TABLE II-3

REDUCTION FACTORS FOR ADDITIONAL CLEARANCES

(Adapted from NESC Rule 232B2e)

Distance from nearer support of crossing span to point of crossing in percentage of crossing span length	Factors[1]
5	0.19
10	0.36
15	0.51
20	0.64
25	0.75
30	0.84
35	0.91
40	0.96
45	0.99
50	1.00

[1]Interpolate for intermediate values.

K. HIGH CONDUCTOR OPERATING TEMPERATURE RULE

This new rule was introduced in the 1977 NESC. It covers the increased clearances which must be added to the basic clearances, if the conductor will operate above 50°C [120°F]. It applies to all types of conductor crossing spans. The rule reads essentially as follows:

> Where supply lines are designed to operate at a conductor temperature above 50°C [120°F] regardless of span length, the minimum clearance at midspan specified for the basic span length shall be increased by the difference between final unloaded sag at a conductor temperature of 15°C [60°F], no wind, and final sag at the following conductor temperature and condition, whichever difference is greater, computed for the crossing span.
>
> 1. 0°C [32°F], no wind, with radial thickness of ice, if any, specified in NESC Rule 250B for the loading district concerned.
> 2. The maximum conductor temperature for which the supply line is designed to operate, with no horizontal displacement.

The application of the rule is not as complicated as first appears. Use the final conductor sag at the maximum high-conductor operating temperature, and simply maintain the basic clearance requirement regardless of span length.

The exception to the above is that if the sag of the ice-loaded conductor is greater than the high-temperature sag, substitute the ice-loaded sag. This exception will be most probable for small conductors in the heavy loading district.

By the nature of rural distribution systems, heavy current loading of the conductors sufficient to cause operating temperatures above 50°C [120°F] will be infrequent in most parts of the United States.

Following are conditions that will most often cause high operating conductor temperatures on rural distribution systems:

- Short, ampacity-designed lines serving heavy industrial, pumping stations, and similar loads;
- Tie lines designed to transfer loads from one substation to another under maintenance or emergency conditions;
- High ambient air temperatures.

It is most probable that high operating temperatures will occur during high ambient air temperature conditions. If the summer peak load on the line is caused by an appreciable amount of air conditioning load, it is obvious that the highest conductor temperature will coincide with the highest air temperature. If the ambient air temperature exceeds 45°C [110°F] on a sunny still day, it is quite likely that the conductor operating temperature of some lines may exceed 50°C [120°F].

In those parts of the country where maximum ambient air temperatures occasionally exceed 50°C [120°F], all conductors including the neutral will also operate above 50°C. It appears that under these conditions, the conductors should be designed under the high operating temperature rules.

In determining conductor high operating temperatures, short-term emergency loading must be considered, even though such loading will occur only for a few minutes. This type of loading is most apt to occur on tie-lines or network systems.

Detailed application of this rule is discussed in Parts IV and V of this design manual.

L. HORIZONTAL BLOWOUT OF CONDUCTOR

Most of the basic horizontal clearance requirements are applied with the conductor displaced from rest by a 290 Pa [6 lb/ft²] wind pressure. This may be reduced to a 190 Pa [4 lb/ft²] wind pressure in areas sheltered by buildings, terrain, or other obstacles. It is not recommended that this reduction be used unless absolutely necessary. Where applicable, the displacement of the conductor shall include deflection of suspension insulators and flexible structures.

The horizontal component of sag of the displaced conductor is added to the basic horizontal clearance required for the specific application.

- **Displacement Equations**

Conductor horizontal displacement due to blowout is determined by the following equation:

$$D_h = D_r\ [\sin(\text{arc tan}\ [W_h/W_v])], \qquad \text{EQ II-3D}$$

or more simply:

$D_h = D_r \times D_f$ EQ II-3E

Where:

$D_f = W_h \div \sqrt{W_h^2 + W_v^2}$ EQ II-3F

D_h = Horizontal displacement, meters or feet

D_r = 15°C [60°F] final resultant conductor sag, meters or feet.

D_f = Displacement factor

W_h = Unit transverse wind load, N/m (Newtons/meter) or lb/ft

W_v = Unit bare conductor weight, N/m or lb/ft

- **Sample Calculation**

The following example demonstrates the application of the equation:

Given: Conductor is 2 ACSR (6/1), 91.4 m (300 ft) span, resultant final conductor sag (D_r) = 1.07 m (3.5 ft), at 60°F with a 290 Pa [6 lb/ft²] wind pressure.

From Appendix B of this design manual:

W_h = 0.1580 lb/ft at 6 lb/ft² wind pressure

W_v = 0.0916 lb/ft

$$D_f = \frac{(0.1580)}{\sqrt{(0.1580)^2 + (0.0916)^2}}$$

$D_f = 0.8651$

Calculate the horizontal component of conductor blowout (D_h)

$D_h = D_r \times D_f$

- **Metric**

$D_h = 1.07 \times 0.8651$

$D_h = 0.93$ m

- **Customary**

$D_h = 3.5 \times 0.8651$

$D_h = 3.03$ ft.

D_f is dimensionless, and will be the same value whether with metric or customary units. It should be noted that for the horizontal clearance calculation, the proper sag to use is the resultant sag at 15°C [60°F] final with a 290 Pa [6 lb/ft²] wind. This is not the 15°C [60°F] unloaded final sag. This data has not usually been provided with sag-tension data, and therefore will have to be obtained or calculated.

Detailed examples of the application of this rule are provided in Part IV of this design manual.

CHAPTER II-4
CLEARANCES ABOVE GROUND, RAILS, AND WATER

A. NESC CLEARANCE RULE 232

This chapter discusses the vertical clearance requirements for span conductors located above the surface of ground, railroad tracks, roadways, and waterways. These clearance requirements are covered under NESC Rule 232.

The minimum basic vertical clearances of the conductors above the surface are given in NESC Table 232-1. Those common to distribution line conductors are also given hereafter in Table II-4.

Each basic clearance requirement given in the tables is subject to additional clearances where the limiting conditions for the basic clearances have been exceeded. The limiting conditions for basic clearances and the additional clearances applicable to distribution lines are as discussed in Chapter II-3.

B. DESCRIPTION OF TABLE II-4 (NESC TABLE 232-1)

Table II-4 is a modification of NESC Table 232-1 and includes only those basic clearance requirements commonly used in design and construction of REA-financed rural distribution systems.

Each clearance requirement included is for a specific clearance category and for a specific voltage class or range. The clearance categories are based on the use of the space between the conductor and surface being crossed or overhung.

On Table II-4, two dimensions are provided for each requirement. The dimension to the left is a soft metric conversion of the NESC clearance value. The dimension on the right, enclosed in parentheses, is the U.S. customary unit of measurement.

C. CLEARANCE CATEGORIES OF TABLE II-4

Each of the vertical clearance categories of NESC Table 232-1 is identified by the nature of the surface underneath the conductors. The required basic clearance is a function of the ordinary use of the space above the surface.

TABLE II-4

MINIMUM BASIC VERTICAL CLEARANCE OF WIRES, CONDUCTORS, AND CABLES ABOVE GROUND, RAILS, OR WATER

(Adapted from NESC Table 232-1)

Clearance Categories	Neutrals Guys m (ft)	Voltage (Phase-to-ground on effectively grounded circuits) 0-750V Services Secondary m (ft)	0.75-15 kV Line Voltage kV 12.5/7.2 · 24.9/14.4 m (ft)	15-50 kV 34.5/19.9 m (ft)
Where wires, conductors, or cables cross over or overhang				
1. Railroad tracks[1]	8.3 (27)[2]	8.3 (27)[2]	8.6 (28)[2]	9.2 (30)[2]
2. Roads and other areas subject to truck traffic[1]	5.5 (18)[2]	5.5 (18)	6.1 (20)	6.7 (22)
3. Residential driveways[1]	3.1 (10)	4.6 (15)[2]	6.1 (20)	6.7 (22)
4. Other land traversed by vehicles[1]	5.5 (18)	5.5 (18)	6.1 (20)	6.7 (22)
5. Spaces or ways accessible to pedestrians only	4.6 (15)[2]	4.6 (15)[2]	4.6 (15)	5.2 (17)
6. Water areas not subject to sailboating[1]	4.6 (15)	4.6 (15)	5.2 (17)	5.2 (17)
7. Water areas subject to sailboating				
a) Less than 20 acres	5.5 (18)	5.5 (18)	6.1 (20)	6.7 (22)
b) 20 to 200 acres	7.9 (26)	7.9 (26)	8.5 (28)	9.1 (30)
c) 200 to 2,000 acres	9.8 (32)	9.8 (32)	10.4 (34)	11.0 (36)
d) Over 2,000 acres	11.6 (38)	11.6 (38)	12.2 (40)	12.8 (42)
8. Areas subject to saiboat launching	Clearances above ground shall be 5 feet greater than in 7 above.			
Where wires, conductors, or cables run along and within the limits of highways or other road rights-of-way but do not overhang the roadway				
9. Roads in urban districts	5.5 (18)[2]	5.5 (18)	6.1 (20)	6.7 (22)
10. Roads in rural districts	4.3 (14)	4.6 (15)	5.5 (18)	6.1 (20)

[1]Clearances listed will generally apply to rural distribution systems.

[2]See NESC Table 232-1 for exceptions and notations.

The categories are discussed below and are numbered identically to Table II-4 and to NESC Table 232-1.

For Categories 1 through 8, the clearances are those required when the conductors cross over or overhang the surface identified by the category.

For Categories 9 and 10, the clearances are those required when the conductors run along roads and within the road rights-of-way but do not overhang the roadway.

Roadway is defined as that portion of the highway, including shoulders, for vehicular use.

Conductor overhang can be described as the infringement of the space above a surface without crossing the surface. In determining overhang requirements, it is necessary to consider all surfaces which the conductor may overhang when displaced horizontally by the wind.

1. Railroad Tracks

These clearances apply where the conductors cross or overhang railroad tracks. In those cases where tunnels, bridges, or other obstacles restrict loads or cars to under 6.1 m (20 feet), clearances can be reduced. See footnotes to NESC Table 232-1. No reductions to the clearances should be made without clearing with railroad officials.

2. Roads and Other Areas Subject to Truck Traffic

These clearances apply where conductors cross or overhang roads, streets, alleys, nonresidential driveways, parking lots, and other areas subject to truck traffic. For the purpose of this rule trucks are defined as any vehicle exceeding 2.4 m (8 feet) in height.

The clearances are based on the assumption that ordinary truck traffic will be limited to approximately 4.3 m (14 feet) because of clearance restrictions under bridge trusses, underpasses, etc. In locations where it is known that loaded vehicles in excess of 4.3 m will be traveling under the conductors, it is recommended that additional clearance be provided.

The clearances do not provide for future surfacing or other alterations to the highway which may reduce the clearance.

3. Residential Driveways

These clearances apply where conductors cross or overhang any residential driveways and those commercial areas not subject to truck traffic. For the purpose of this rule, trucks are defined as any vehicle exceeding 2.4 m (8 feet).

4. Other Land Traversed by Vehicles

These clearances apply where conductors cross over or overhang other land traversed by vehicles. The lands include agricultural lands such as cultivated, grazing, forest, orchard, and other lands where trucks, equipment, and other vehicles can normally be expected to travel or work. The clearances required are the same as for roadways and, it is assumed, that these vehicles which traverse the land will also travel on the roads and vice versa.

Like the vehicles which travel on the roads, it can be assumed these vehicles will ordinarily be limited to approximately 4.3 m (14 feet) in traveling and operating height.

Where lines are located adjacent to these lands so that the conductor will overhang or can blow out over these other lands, the conductor clearance will be subject to this clearance category requirement.

This rule was introduced by the 1977 NESC. Minor modifications in wording were made by the 1981 NESC. The 1977 NESC stated that the rule applied to lands traversed by vehicles under 14 feet. The 1981 NESC removed this statement. If local conditions exist which require greater than ordinary clearances, additional clearance is recommended.

5. Spaces or Ways Accessible to Pedestrians Only

These clearances provide for reduced clearance where the conductors cross spaces and ways accessible only to pedestrians.

The 1981 NESC defines spaces and ways accessible only to pedestrians as areas where vehicular traffic is not normally encountered or not reasonably anticipated. These clearances apply only to crossings of such areas.

These clearances should be applied carefully. If it is reasonably anticipated that anything other than a person on foot may get under the line, such as a person riding a horse, the line should not be considered to be accessible only to pedestrians and another clearance category should be used. It is expected that this type of clearance will be used infrequently.

6. Water Areas Not Subject to Sailboating

These clearances apply where conductors cross or overhang water areas not suitable for

sailboating or where sailboating is prohibited. These clearances apply only to that portion of the span above the water. The clearance requirements of the adjacent land may control the design of the span.

Where the U.S. Army Corps of Engineers or the state, or a surrogate thereof has issued a crossing permit, clearances of that permit shall govern. It is not recommended that clearances be less than NESC requirements, in any event. This paragraph also applies to Categories 7 and 8 following.

The Clearance Categories 6, 7, and 8 covering water areas were introduced by the 1977 NESC. Minor changes in wording were made in the 1981 NESC.

7. Water Areas Subject to Sailboating

These clearances apply where conductors cross or overhang water areas suitable for sailboating including lakes, ponds, reservoirs, tidal waters, rivers, and streams with unobstructed surface areas as indicated by Table II-4.

For controlled impoundments, the surface area and corresponding clearances shall be based upon the design high water level. For other waters, the surface area shall be that enclosed by its annual high water mark, and clearances shall be based on the normal flood level. The clearance over rivers, streams, and canals shall be based upon the largest surface area of any 1.61 km (1 mile) long segment which includes the crossing. The clearance over a canal, river, or stream normally used to provide access for sailboats to a larger body of water shall be the same as that required for the larger body of water.

See Footnote 18 of NESC Table 232-1 for clearance exceptions where an overwater obstruction restricts vessel heights.

8. Areas Subject to Sailboat Launching

These clearances apply where conductors cross over or overhang public or private land and water areas posted for rigging or launching sailboats.

9. Along Roads in Urban Districts

These clearances apply where conductors run along and within the limits of highways, streets, alleys, and other road rights-of-way in urban districts but do not overhang the roadway.

Urban districts are defined as thickly settled areas (whether in cities or suburbs) or where congested traffic often occurs. A highway, even though in thinly settled areas on which the traffic is often very heavy, is considered as urban.

10. Along Roads in Rural Districts

These clearances apply where conductors run along and within the limits of highways or other road rights-of-way but do not overhang the roadway. The clearances apply only where it is unlikely that vehicles will be crossing under the line.

Rural districts are defined as all places not urban. This may include thinly settled areas within city limits. See Category 9 above for definition of urban districts.

If the conductor overhangs the roadway (including the shoulder), road crossing clearance must be provided. Likewise, if at the outer limit of the road rights-of-way, the conductor overhangs agricultural land, "other land" crossing clearance must be provided. If vehicles do cross under the conductor within the limits of the rights-of-way for highway or utility maintenance or for agricultural or other purposes, "other land" crossing clearance should be provided at those locations where it is likely that vehicles will cross under the conductors.

D. PREDOMINANT CLEARANCE REQUIREMENT FOR RURAL LINES

Prior to 1977 the predominant vertical clearance used for distribution lines was the clearance of Category 10, Along Roads in Rural Districts. Until the 1977 NESC introduced Category 4, Other Land Traversed by Vehicles, there was no other applicable specific clearance except at road and other crossings. Because of this, staking tables and other design aids were based on the along-the-road clearance.

It was natural to use these design aids for lines constructed along fence rows and across agricultural lands. The great majority of lines were so designed and constructed. It does appear that lines so designed did, in fact, provide adequate safeguards in the great majority of cases. However, times are changing and larger vehicles and equipment are being used on agricultural lands.

The majority of rural distribution lines run along rural roads but usually at the limit of the road rights-of-way, either on the field side or road side of the rights-of-way fence. As such, the great majority of lines are located so that the

conductors overhang agricultural land during conductor blow out, if not during still air. This, together with other added restrictions on use of the along-the-road clearance, will require use of the other land clearance for most spans of the rural lines.

The clearance requirements of Category 4, Other Land Traversed by Vehicles, are the same as for road crossings and farm drive crossings. Therefore, designs based on this category can be used throughout the line with only a few special exceptions.

CHAPTER II-5
CLEARANCES BETWEEN CONDUCTORS SUPPORTED BY DIFFERENT STRUCTURES

A. NESC CLEARANCE RULE 233

This chapter discusses the clearances between conductors which are carried on different supporting structures and either cross or are adjacent to each other and in close proximity. These clearance requirements are covered by NESC Rule 233. Major revisions of this rule were made in both the 1977 NESC and 1981 NESC.

The clearance requirements of the NESC Rule 233 are unique in that the clearances are not applied between the surfaces of the conductors but instead are applied between the surfaces of imaginary envelopes which surround the conductors. The determination of the dimensions of these envelopes is quite complex and complicates the calculation of clearances particularly when the vertical planes of the conductor spans are not perpendicular or parallel.

Additional clearance requirements are applied to the dimensions of the conductor movement envelope rather than to the basic clearances.

Crossings should be made on a common supporting structure, where practical. Where crossings must be made in the spans, the clearance in any direction between crossing or adjacent conductors carried on different supporting structures shall not be less than the horizontal clearance required by NESC Rule 233B or the vertical clearance required by NESC Rule 233C, as applicable.

The applicable clearance, horizontal or vertical, required between conductors shall be determined by a clearance envelope applied at the points on the relevant segments of the conductor movement envelopes at the location where the two conductors would be the closest together, as shown in Figure II-1. The conductor movement envelopes shall be determined for each conductor involved in accordance with NESC Rule 233A1. The clearance envelope shall be determined in accordance with NESC Rule 233A2.

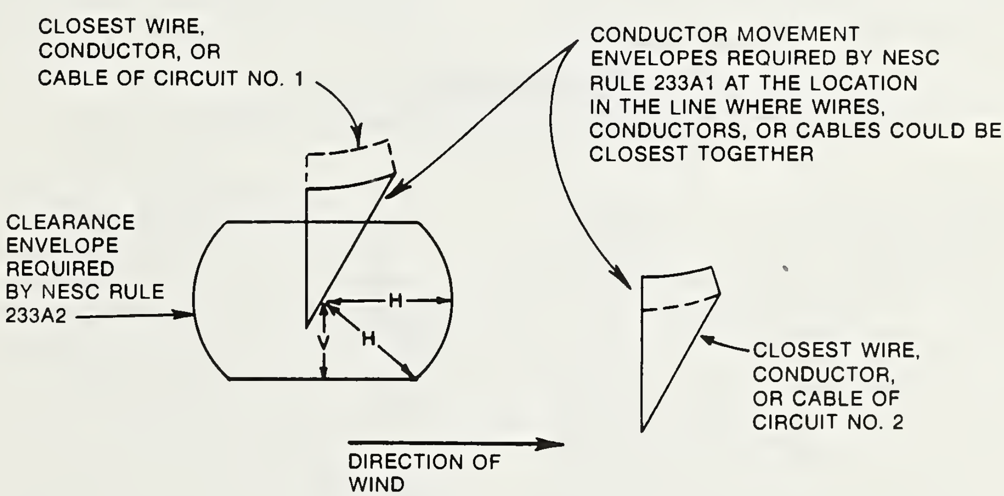


FIGURE II-1

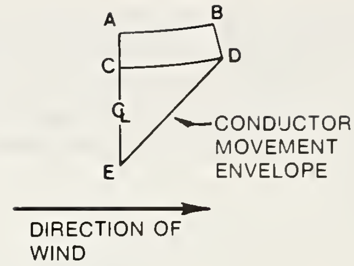
B. CONDUCTOR MOVEMENT ENVELOPE

The perimeter of the conductor movement envelope describes the limit of all possible movements of the conductor under the conditions given. Therefore, any point on the perimeter can be considered as being an energized conductor at some time. Thus, in determining clearance requirements, the surface of the envelope is treated as a conductor.

The conductor movement envelope shall be developed from the locus of the most displaced conductor positions shown in Figure II-2. The conductor positions A-E which define the conductor movement envelope include the effects of the basic conditions shown in Figure II-2 and the sag increases specified in the NESC Rule 233A1b as applicable.

The direction of the wind should be that which produces the minimum separation. It should be noted that the same wind acts on both conductors and both are blown in the same direction. The displacement of the conductors due to blowout includes the deflection of suspension insulators and flexible structures.

The dimension C-E of the envelope represents required additional vertical clearances. For distribution line voltages, the additional clearances are those due to sag increase as discussed in Chapter II-3. The limiting condition for basic spans applies. The incremental increase ratio factor is the same as is applied to railroad crossings.



CONDUCTOR MOVEMENT ENVELOPE

Point	Conductor Temperature	Sag	Ice Loading	Wind Displacement
A	15°C [60°F]	initial	none	none
B	15°C [60°F]	initial	none	300 Pa [6 lb per sq ft]
C	15°C [60°F]	final	none	none
D	15°C [60°F]	final	none	300 Pa [6 lb per sq ft]
E_1	The greater of 50°C [120°F] or maximum operating	final	none	none
E_2	0°C [32°F]	final	as applicable	none

FIGURE II-2

Since the dimensions of the conductor envelope are functions of conductor sag and blowout, the dimensions are maximum at midspan and approach zero at the supporting structure.

C. CLEARANCE ENVELOPE

The clearance envelope shown in Figure II-3 shall be determined by the horizontal clearance (H) required by NESC Rule 233B and the vertical clearance (V) required by NESC Rule 233C.

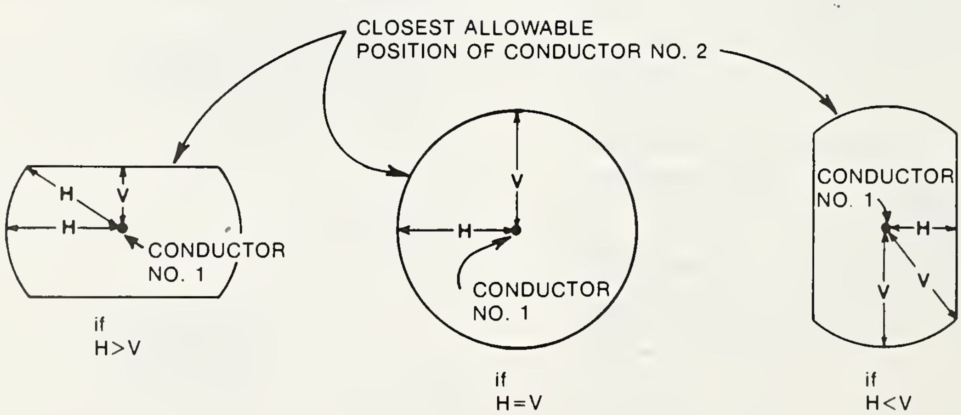


FIGURE II-3

D. BASIC HORIZONTAL AND VERTICAL CLEARANCES

The basic horizontal clearances are covered by NESC Rule 233B1 and the basic vertical clearances by NESC Rule 233B2. For distribution voltage classes there are no adjustments required for these clearance requirements. The clearance requirements common to rural distribution lines are shown on Table II-5, which is a modification of NESC Table 233-1.

E. PRACTICAL APPLICATION OF NESC RULE 233

From the preceding discussion, it is obvious that Rule 233 is one which can be very difficult to apply. The computations required are such that they can be best accomplished with the aid of an electronic computer and even then a very sophisticated program would be required.

The practical solution to the problem is to avoid the need for applying the rule or to provide sufficient extra clearance so that there will be no need for exact computations. For distribution lines, the added construction costs for avoiding the need for exact computations will, in most cases, be less than the engineering costs for preparing the exact computations required to determine the exact minimum clearances.

The rule covers conductor separations for conditions varying from parallel lines to perpendicular crossing of lines and for every possible skewed angle crossing between these extremes.

The need for applying the rule can be avoided by joint use of poles for supporting the conductors. The joint use may be for either parallel circuits or crossing of circuits. In either case, NESC Rule 235 would then apply rather than this rule.

For parallel circuits, the detailed computations can be avoided or replaced by simple computations by one of the following:

- Computations will generally not be required if the lines are located so that the structures are not in conflict. See the definition of structure conflict in NESC Section 2.
- There will be adequate clearance between conductors of the two lines if in every span of the upper circuit, the low point of sag (Point E in Figure II-2) of the lowest conductor of the upper circuit maintains the required vertical clearance above a straight line between the conductor supports of the highest conductor of the lower circuit.
- There will be adequate clearance between conductors of the two lines if the lines are separated horizontally so that the maximum horizontal blowout of the conductors of each of the two lines is such that the required horizontal clearance is maintained to a vertical plane through the conductor supports of the closest conductor of the other circuit.

For line crossings, it is recommended that the crossings be made as perpendicular as possible. It is also recommended that the crossing be made close to the supporting structure of the higher circuit. There will be adequate clearance if the low point of sag (Point E in Figure II-2) of the lowest conductor of the higher circuit maintains the required vertical clearance to a straight line between the conductor supports of the highest conductor of the lower circuit. Methods for making this determination are discussed in Chapter VI-1 of this design manual.

CHAPTER II-6
CLEARANCES FROM BUILDINGS AND OTHER OBJECTS

A. NESC CLEARANCE RULE 234

This chapter discusses the vertical, horizontal, and diagonal clearance requirements for span conductors which cross over or pass by objects such as buildings, signs, tanks, windmills, and other installations. These clearance requirements are covered by NESC Rule 234.

The occasions when there will be need to apply these rules are far fewer for rural areas than for urban areas. The application of the horizontal clearances to these objects will occur more frequently than the vertical and diagonal requirements. It is recommended that crossing over these objects be avoided wherever possible.

The minimum basic vertical and horizontal clearance requirements of conductors above and adjacent to the exposed surfaces of buildings and other objects are given in NESC Rules 234A, 234B, 234C, 234D, 234E, and 234H and Tables 234-1, 234-2, and 234-3. Those most likely to be encountered in the design and construction of rural distribution lines are given in Table II-6.

TABLE II-5

BASIC VERTICAL CLEARANCE OF WIRES, CONDUCTORS, AND CABLES CARRIED ON DIFFERENT SUPPORTING STRUCTURES

(Adapted from NESC Table 233-1)

(Voltages are phase-to-ground for effectively grounded circuits and those other circuits where all ground faults are cleared by promptly de-energizing the faulted section, both initially and following subsequent breaker operations.)

Upper Level	Open supply conductors and service cables 0 to 750 V		Open supply conductors and service drops		Guys, span wires, and neutral conductors
Lower Level	Line conductors m (ft)	Service drops m (ft)	750 V to 8.7 kV m (ft)	8.7 to 50 kV m (ft)	m (ft)
Communications, conductors, cables, and messengers	1.22 (4)	0.61 (2)[1]	1.22 (4)[3]	1.83 (6)	0.61 (2)
Supply cables and messengers meeting Rule 230C1 (including service drops over 750 V)	0.61 (2)[1]	0.61 (2)[1]	0.61 (2)[1]	1.22 (4)	0.61 (2)[1]
Supply cables and messengers of any voltage meeting Rule 230C2 or 230C3 (including service drops over 750 V)	0.61 (2)[1]	0.61 (2)[1]	0.61 (2)[1]	1.22 (4)	0.61 (2)
Open supply service drops (0 to 750 V)	0.61 (2)[1]	0.61 (2)[1]	1.22 (4)	1.22 (4)	0.61 (2)
Open supply conductors					
(0 to 750 V)	0.61 (2)[1]	0.61 (2)[1]	0.61 (2)[1]	1.22 (4)	0.61 (2)
750 V to 8.7 kV	0.61 (2)[1]	----[2]	0.61 (2)[1]	1.22 (4)	1.22 (4)
8.7 to 50 kV	----[2]	----[2]	----[2]	1.22 (4)	1.22 (4)
Trolley and electrified railroad contact conductors and associated span and messenger wires	1.22 (4)	1.22 (4)	1.83 (6)	1.83 (6)	1.22 (4)
Guys, span wires, neutral conductors meeting Rule 230E1, and lightning protection wires	0.61 (2)[1]	0.61 (2)[1]	1.22 (4)	1.22 (4)	0.61 (2)

[1]Where a 2 ft. clearance is required at 60°F, and where conditions are such that the sag in the upper conductor would increase more than 1.5 ft. at the crossing point under any condition of sag stated in NESC Rule 233A 1b and c, and the 2 ft. clearance shall be increased by the amount of sag increase less 1.5 ft.

[2]Crossing not recommended.

[3]This clearance shall be increased to 6 ft. where the supply wires cross over a communication line within 6 ft. horizontally of a communication structure.

B. DESCRIPTION OF TABLE II-6

Table II-6 includes selected basic clearance requirements which are most likely to be encountered with rural distribution lines.

Each basic clearance requirement included is for a specific vertical or horizontal clearance category and for a specific voltage class. The clearance categories are based on the type and use of the object being crossed over or passed by.

Clearance dimensions are provided for both metric and customary units of measurement.

C. APPLICATION OF CLEARANCES OF TABLE II-6

The following application guides apply to all clearance categories listed on Table II-6.

1. Vertical Clearances

The basic vertical clearance requirement given in Table II-6 is subject to additional clearances where the limiting conditions for the basic clearances have been exceeded. The limitations for vertical clearances and the applicable additional clearances for these distribution voltages are as discussed in Chapter II-3.

The total vertical clearance applied to these clearance categories is the sum of the basic vertical clearance and applicable additional clearances.

2. Horizontal Clearances

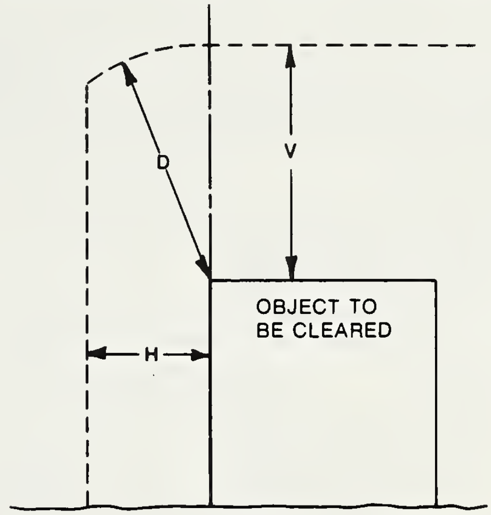
The basic horizontal clearance requirement given in Table II-6 is applied with the conductor displaced from rest by wind. The magnitude of this conductor blowout is determined as discussed in Chapter II-3.

The total horizontal clearance applied to these clearance categories is the sum of the basic horizontal clearance and conductor displacement.

3. Diagonal Clearance

The horizontal clearance governs above the roof level or top of an installation to the point where the diagonal equals the vertical clearance requirements. Similarly, the horizontal clearance governs above or below projections from buildings, signs, or other installations to the point where the diagonal equals the vertical clearance requirement.

Figure II-4 illustrates the application of the diagonal clearance requirement between conductors and a building or other object. No conductor may be closer to the object than defined by the dashed line. The diagonal clearance is equal to the vertical clearance. The clearances are total minimum clearances including the basic clearance plus any required increases.



V = MINIMUM VERTICAL CLEARANCE
H = MINIMUM HORIZONTAL CLEARANCE
D = MINIMUM DIAGONAL CLEARANCE
D = V

FIGURE II-4

D. CLEARANCES TO OTHER OBJECTS

The NESC provides clearances to other objects not covered by Table II-6. In rural areas the occasions where it will be necessary to apply these rules will be few. It is recommended that wherever possible, these objects be avoided. The rules are listed for reference.

- Rule 234D.

  Clearances of conductors from bridges;

- Rule 234E.

  Clearance of conductors installed over or near swimming pools.

CHAPTER II-7
CLEARANCES FOR CONDUCTORS ON SAME SUPPORT

A. NESC CLEARANCE RULE 235

This chapter discusses the horizontal, vertical, and diagonal clearance requirements between line conductors when carried on the same supporting structures. These requirements are covered under NESC Rule 235.

TABLE II-6

BASIC CLEARANCE OF CONDUCTORS PASSING BY BUT NOT ATTACHED TO BUILDINGS OR OTHER INSTALLATIONS

(Adapted from NESC Table 234-1)

Clearance Categories[1]	Neutrals Guys m (ft)	0-750V Services Secondary m (ft)	0.75-8.7 kV 12.5/7.2 kV m (ft)	8.7-15 kV 24.9/14.4 kV m (ft)	15-50 kV 34.5/19.9 kV m (ft)
			Voltage (Phase-to-ground on effectively grounded circuits) / Voltage Class		
1. Buildings					
Horizontal:					
To walls[1], projections[1], unguarded windows[1], balconies, and areas accessible to pedestrians	0.9 (3)	1.5 (5)	1.5 (5)	2.4 (8)	3.0 (10)
Vertical:					
Above or below roofs or projections not accessible to pedestrians[1]	0.9 (3)	3.0 (10)	3.0 (10)	3.0 (10)	3.7 (12)
Above or below balconies and roofs accessible to pedestrians[1]	2.4 (8)	4.6 (15)	4.6 (15)	4.6 (15)	5.2 (17)
Above roofs accessible to truck traffic	5.5 (18)	5.5 (18)	6.1 (20)	6.1 (20)	6.7 (22)
Above roofs accessible to vehicles but not to truck traffic[1]	3.1 (10)	4.6 (15)	6.1 (20)	6.1 (20)	3.0 (10)
2. Other Installations Not Classified as Buildings					
Horizontal:[1]	0.9 (3)	1.5 (5)	1.5 (5)	2.4 (8)	3.0 (10)
Vertical:[1]	0.9 (3)	1.5 (5)	2.4 (8)	2.4 (8)	3.0 (10)
3. Other Supporting Structures					
Horizontal:[1]	1.5 (5)	1.5 (5)	1.5 (5)	1.5 (5)	1.5 (5)
Vertical:[1]	1.8 (6)	1.8 (6)	1.8 (6)	2.1 (7)	2.1 (7)

[1]Clearances normally apply on rural distribution systems. See NESC Table 234-1 for exceptions and notations.

The following discussion is generally limited to those portions of NESC Rule 235 which apply to conductors of 12.5/7.2 kV, 24.9/14.4 kV, and 34.5/19.9 kV effectively grounded rural distribution circuits carried on supports of the types covered by REA standard drawings, together with those types of secondary, service, and communication conductors commonly found as underbuild on such circuits.

For these rules, conductor voltage is the voltage between conductors. Voltages between two conductors of different circuits shall be the vector difference of the voltages of both circuits or the line-to-ground voltage of the higher voltage circuit, whichever is greater. If the two conductors of different circuits are of like phase, the lower voltage conductor shall be considered grounded for the purpose of determining the clearance between them. If the vector relationship between the conductors of different circuits is unknown, the voltages between the conductors should be taken as the sum of the line-to-ground voltages of the two circuits.

B. HORIZONTAL CLEARANCES BETWEEN LINE CONDUCTORS

Horizontal clearances between two conductors carried by the same support are covered by NESC Rule 235B.

1. Basic Clearances

The minimum horizontal clearance (C_h) between conductors at the supports shall be not less than the following:

For voltages less than 8.7 kV:

C_h = 0.305 meters. EQ II-7A

C_h = 12 inches. EQ II-7B

For voltages higher than 8.7 kV:

C_h = 0.305 + 0.01 (kV - 8.7) meters. EQ II-7C

C_h = 12 + 0.4 (kV - 8.7) inches. EQ II-7D

2. Clearances According to Sag

NESC requires that the clearances be increased if the span sag of the conductor is such that the clearance according to sag is greater than the above clearances. NESC Tables 235-2 and 235-3 provide horizontal clearances as a function of voltage and sag.

The horizontal clearance requirements are based on the conductors at a conductor temperature of 15°C [60°F], at final unloaded sag with no wind.

REA standard pole top assembly drawings for 12.5/7.2 kV, 24.9/14.4 kV, and 34.5/19.9 kV cir cuits are designed to provide adequate horizontal separation for most applications for which they normally would be used. It is recommended that the standard drawing dimensions be considered minimum.

It may be necessary to check these dimensions for very long spans. Since the separation is known, what is desired is the permissible sag which can be determined by the following equations. Only the large conductor equations are provided as the use of conductors smaller than No. 2 AWG are not generally recommended for these long spans when the horizontal clearances are phase-to-phase.

The NESC equation for horizontal clearance:

C_h = 0.3 in/kV + 8 $\sqrt{D/12}$ inches, EQ II-7E

Where:

D = sag in inches

Can also be expressed as:

C_h = 0.3 in/kV + 2.31 $\sqrt{D}$, EQ II-7F

Where:

C_h and D are in inches

C_h = 0.025 ft/kV + 0.667 $\sqrt{D}$, EQ II-7G

Where:

C_h and D are in feet

C_h = 0.0076 m/kV + 0.368 $\sqrt{D}$, EQ II-7H

Where:

C_h and D are in meters

Then the maximum permissible sag for a separation of C_h:

D = 0.187 (C_h - 0.3 in/kV)^2, EQ II-7I

Where:

C_h and D are in inches

D = 2.25 (C_h - 0.025 ft/kV)^2, EQ II-7J

Where:

C_h and D are in feet

D = 7.38 (C_h - 0.0076 m/kV)^2, EQ II-7K

Where:

C_h and D are in meters

C. VERTICAL CLEARANCES BETWEEN LINE CONDUCTORS

1. General

Vertical clearances between conductors carried on the same support are covered by NESC Rule 235C. Prior to 1977 these clearances were covered under NESC Rule 238. For the

1977 NESC the rule was completely changed and moved under Rule 235. Minor changes in wording were made in the 1981 NESC.

The current basic clearances shown in NESC Table 235-5 and Table II-7 show decreases from the rules prior to 1977. However, the application of the associated current rules in many cases will require an increase in separation between conductors on joint-use pole lines.

For power conductors, the upper conductor is to be considered at its maximum design operating temperature, while the lower conductor is to be taken at the normal temperature of 15°C [60°F].

These differences in temperature will have to be considered for distribution underbuild on transmission lines, multiple circuits, and for phase conductors located above neutral conductors. These can all be of significance, particularly when high operating temperatures are concerned.

Based on associated rules, it has to be assumed that a distribution phase conductor, located above a neutral, will have an operating temperature of 120°F unless designated for a higher operating temperature.

The current edition of REA Bulletin 62-1, Design Manual for High-Voltage Transmission Lines, indicates that most transmission lines are designed for 75°C [167°F] to 100°C [212°F] conductor operating temperatures. Heavy distribution tie-line feeders may operate in the same range.

This clearance requirement can be a span limiting condition, especially where a phase conductor is operating at high temperature above a neutral conductor. In some cases, it can be more limiting than the phase-to-ground clearance. Where this is a problem and the long span cannot be eliminated, the problem may have to be corrected by providing more separation between the phase conductor and neutral.

2. Determination of Clearance

The minimum basic vertical clearance between conductors carried on the same supports is found in Table II-7. The basic clearances are for conductors of the same or different circuits and for conductor-to-conductor voltages of 0 to 50 kV. There are no other limiting conditions for the basic clearances.

The additional clearance requirements for distribution class voltages are for conductors of different sags carried on the same supports and are as follows:

- Line conductors, supported at different levels on the same structure, shall have vertical clearances at the supporting structures so adjusted that the minimum clearance at any point in the span shall be not less than the following with the upper conductor at its final unloaded sag at the maximum temperature for which the conductor is designed to operate and the lower conductor at its final unloaded sag at 15°C [60°F].

  For voltages less than 50 kV between conductors, the minimum clearance shall not be less than 75 percent of that required at the supports by Table II-7.

- In cases where conductors of different sizes are strung to the same sag for the sake of appearance or to maintain unreduced clearance throughout storms, the chosen sag should be such as will keep the smallest conductor involved in compliance with the tension limitation requirements of NESC Rule 261H2.

If the conductor-to-conductor clearance involves a transmission conductor above a distribution line conductor, refer to NESC Rule 235C and to Chapter VI of REA Bulletin 62-1, Design Manual for High Voltage Transmission Lines.

3. Table II-7

Table II-7 is a modification of NESC Table 235-5 and includes only those basic clearance requirements commonly used in design of and construction of REA-financed rural distribution systems.

4. Application of Rule

REA standard drawings for distribution primary supports are designed to provide adequate vertical separation for most applications where normally used. It is recommended that the REA standard drawing dimensions be used as a minimum.

Methods for determining the maximum permissible spans based on vertical clearances between conductors are given in Part V of this design manual.

D. DIAGONAL CLEARANCE BETWEEN LINE CONDUCTORS

The clearance in any direction between conductors carried by the same supports is covered by NESC Rule 235G. This rule was introduced by the 1977 NESC.

TABLE II-7

MINIMUM BASIC VERTICAL CLEARANCE AT SUPPORTS BETWEEN LINE CONDUCTORS

(Adapted from NESC Table 235-5)

(All voltages are between conductors involved except for railway feeders, which are to ground.)

Conductors usually at upper levels / Conductors usually at lower levels	Open supply conductors, services and multigrounded neutrals: 0 to 750 V m (in)	Open supply line conductors and cables of any voltage meeting Rule 230D[1]: 750 V to 8.7 kV m (in)	8.7 to 15 kV m (in)	15 to 50 kV: Same utility m (in)	15 to 50 kV: Different utilities m (in)
Communication conductors:					
General	1.02 (40)[1]	1.02 (40)	1.53 (60)	1.02 (40)	1.53 (60)
Supply conductors:					
0 to 750 V and multigrounded neutrals	0.41 (16)	0.41 (16)[1]	1.02 (40)	1.02 (40)	1.53 (60)
750 V to 8.7 kV		0.41 (16)[1]	1.02 (40)	1.02 (40)	1.53 (60)
8.7 kV to 15 kV					
If worked on alive with live line tools, and adjacent circuits are neither de-energized nor covered with shields or protectors.			1.02 (40)	1.02 (40)	1.53 (60)
If not worked on alive except when adjacent circuits (either above or below) are de-energized or covered by shields or protectors, or by the use of live line tools not requiring linemen to go between live wires.			0.41 (16)	1.02 (40)[2]	1.02 (40)[2]
Exceeding 15 kV, but not exceeding 50 kV				1.02 (40)[2]	1.02 (40)[2]

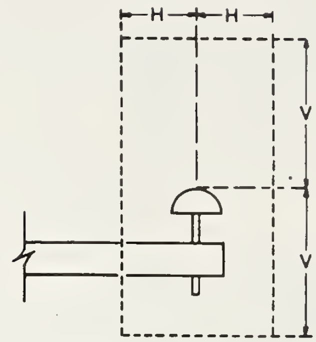
[1]See NESC Table 235-5 for exceptions and notations.

[2]These values do not apply to conductors of the same support.

These clearances are determined by the simultaneous application of the horizontal and vertical clearance rules. No conductor may be closer to any other conductor than defined by the dashed line on Figure II-5, where C_v and C_h are determined in accordance with the preceding discussion of rules for vertical and horizontal separation of conductors carried on the same supports.

The most difficult application of this rule, and at the same time an application which will most frequently cause limiting of spans of REA construction, occurs where spans are rolling from flat to vertical configurations; i.e., the span between C1 and C4 structures. In this example, the most sensitive separation is between the neutral and the crossarm phase conductor, located on the same side of the pole as the neutral, when these are rolled so they are in adjacent positions on the C4 structure.

Methods for determining the maximum permissible spans based on diagonal clearances between conductors are given in Part V of this design manual.



V = MINIMUM VERTICAL CLEARANCE

H = MINIMUM HORIZONTAL CLEARANCE

FIGURE II-5

CHAPTER II-8
MISCELLANEOUS CLEARANCE RULES

A. MISCELLANEOUS NESC CLEARANCE RULES

This chapter covers miscellaneous NESC clearance rules. NESC Rules 236 and 237 concerning climbing space and working space are discussed. Attention is called to those other NESC clearance rules applicable to distribution lines but which are not discussed in detail in this design manual.

B. NESC CLIMBING SPACE RULE 236

NESC Rule 236 requires that climbing space be provided for those portions of a pole which workers ascend. The dimensional requirements for climbing space for the primary conductor voltages normally encountered on REA-financed rural distribution systems can be seen in Table II-8.

TABLE II-8

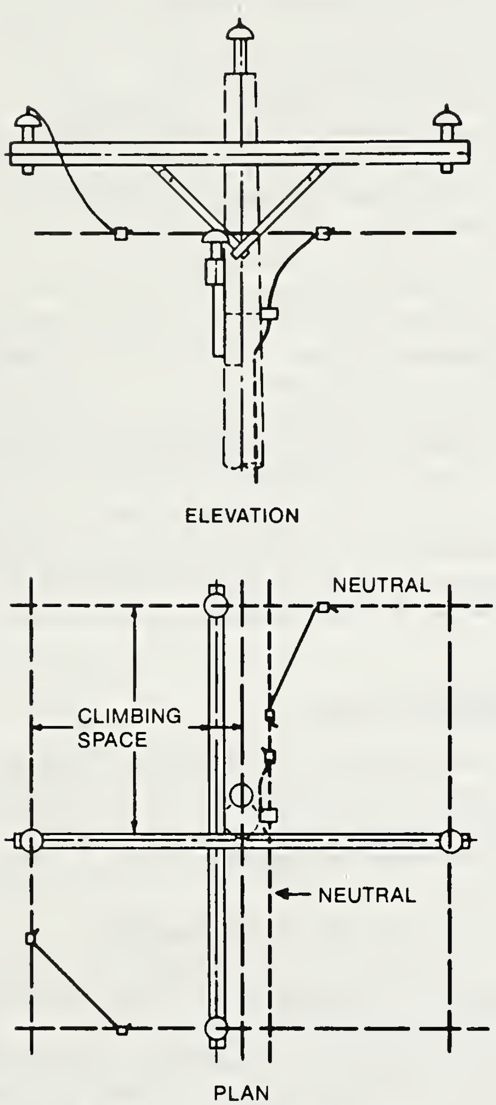
CLEARANCE BETWEEN CONDUCTORS BOUNDING THE CLIMBING SPACE

(Adapted from NESC Rule 236E.)

Voltage	Horizontal Dimension	Vertical Dimension[1]
12.5/7.2 kV	0.76 meters square (30 inches square)	1.02 meters (40 inches)
24.9/14.4 kV	0.91 meters square (36 inches square)	1.02 meters (40 inches)
34.5/19.9 kV	1.02 meters (40 inches square)	1.02 meters (40 inches)

[1]The vertical clearance dimension is above and below the limiting conductor.

Figure II-6 provides an example of unobstructed climbing space.



EXAMPLE OF UNOBSTRUCTED CLIMBING SPACE

FIGURE II-6

Climbing space may be provided on one side or corner of the pole. When the pole or a portion of the pole is located within the climbing space, either at a corner or on one side, it should not be considered as an obstruction to the climbing space.

Climbing space may be shifted from one position on the pole to another, providing the vertical overlap of the two vertical sections is at least 40 inches and there are no obstructions in the overlapping sections.

Vertical conductor runs should not be installed in the climbing space except when installed in conduit. Conduit runs should not interfere with the climbing of poles.

It is desirable that bolt ends not project into the climbing space. In any case, bolt ends should not project from any part of the pole more than two and one-half inches.

C. NESC WORKING SPACE RULE 237

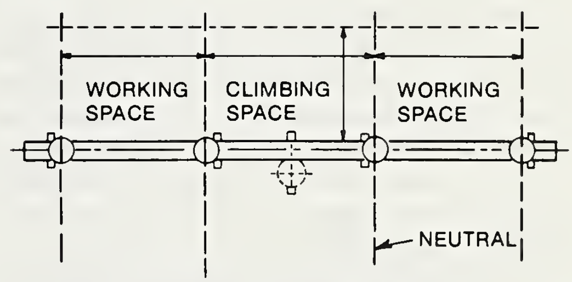
NESC Rule 237 requires that working spaces be provided on the climbing face of the pole at each side of the pole.

Working space is significant only on poles carrying conductors at two or more levels — double circuit construction, for example. Unobstructed working space should be provided on the climbing face of the pole at each side of the climbing space.

The working space extends from the outer limit of the climbing space to the outermost pin positions on the crossarm. As measured from the face of the crossarm (in line with the conductors) the working space should be not less than the climbing space required by the conductor voltage. See Table II-8 for climbing space dimensions.

The height of the working space should be not less than that required for vertical separation of line conductors and should not be obstructed by vertical or lateral conductors.

Figure II-7 provides an example of working space.



EXAMPLE OF UNOBSTRUCTED WORKING SPACE

FIGURE II-7

D. OTHER NESC CLEARANCE RULES

These rules are self-explanatory in the NESC or have only minor impact on rural distribution lines. Refer to the NESC.

1. NESC Rule 231. Clearances of Supporting Structures from Other Objects

This rule specifies minimum distances that supporting structures including arms and braces must be from fire hydrants, streets, roads, highways, street curbs, and railroad tracks.

2. NESC Rule 232C. Minimum Vertical Clearances of Rigid Live Parts Above Ground

This rule has been revised by both the 1977 NESC and 1981 NESC. Clearances are provided for unguarded live parts such as potheads, transformer bushings, surge arresters, and short lengths of supply conductors.

3. NESC Rule 234H. Clearance to Rail Cars

This rule specifies minimum horizontal, vertical, and diagonal clearances from conductors to rail cars where lines run along railroad tracks.

4. NESC Rule 239. Clearances of Vertical and Lateral Conductors from Other Wires and Surfaces on the Same Support

This rule covers clearance requirements as listed below. Refer to the NESC for details.

- Conductors not in conduit;
- Mechanical protection near ground;
- Requirements for vertical and lateral supply conductors on supply line structures or within supply space on jointly used structures;
- Requirements for vertical and lateral communication conductors within the communication space on jointly used poles;
- Requirements for vertical supply conductors passing through communication space on jointly used structures;
- Requirements for vertical communication conductors passing through supply space on jointly used structures.

This rule, for example, covers the required spacing from the pole center line for a vertical jumper from the line conductor level to apparatus terminal below.

CHAPTER II-9
GRADES OF CONSTRUCTION

A. NESC SECTION 24 - GRADES OF CONSTRUCTION

The NESC rules concerning grades of construction are covered in Section 24 of the NESC.

A possibility of danger results from the existence of overhead lines in any location. The degree of hazard that would exist, should an overhead conductor fall, is related to the voltage of the conductor, the nature of the surface, object or other conductors onto which it might fall, and to the number of people who would be directly or indirectly exposed to risk of injury as the result of the fall.

The probability of the conductor falling is reduced by increasing the strength of the line.

In Section 24 of the NESC, for electric supply lines, three different degrees of hazard are recognized together with three corresponding grades of construction to alleviate the degrees of hazard. These grades of construction are identified as B, C, and N.

Strength requirements for Grades B and C are covered under NESC Rule 261, with Grade B being the stronger. Grade N construction is recognized under NESC Rule 263. However, essentially no specific strength requirements are provided.

REA-financed rural distribution lines are required by REA Bulletin 40-7, National Electrical Safety Code, to meet or exceed the requirements of the NESC Grade C construction as a minimum.

B. APPLICATION OF GRADES

The grade of construction for the conductor supports is determined by the grade of construction required by the span conductors.

The grade of construction for supply conductors is determined by the conductor voltage, whether the conductor is open or insulated cable, whether the conductor is in an urban or rural area, and the nature of other conductors or surface below the conductor. NESC Table 242-1 indicates the proper grade of construction for supply conductors alone, at crossing, or on the same structures with other conductors.

Table II-9 on the following page is a condensation of NESC Table 242-1 and shows only those grades of construction common to rural distribution lines.

Note 1 of Table II-9 indicates that Grade N construction is not applicable to systems of REA borrowers. For lines to satisfy the requirements of REA Bulletin 40-7, where the table lists Grade N construction, substitute Grade C. The

TABLE II-9

GRADES OF CONSTRUCTION FOR SUPPLY CONDUCTORS ALONE, AT CROSSING, OR ON THE SAME STRUCTURES WITH OTHER CONDUCTORS

(Adapted from NESC Table 242-1)

(The voltages listed in this table are line to ground values for: effective grounded ac circuits, or two wire grounded circuits; otherwise line to line values shall be used. The grade of construction for supply conductors, as indicated across the top of the table, must also meet the requirements for any lines at lower levels except when otherwise noted.)

Supply conductors at higher levels	Constant-potential supply conductors					
	0-0.75 kV		0.75-8.7 kV		Exceeding 8.7 kV	
Conductors, tracks and rights-of-way at lower levels	Urban Open or Cable	Rural Open or Cable	Urban Open	Rural Open	Urban Open	Rural Open
Common or public rights-of-way	N[1]	N[1]	C	N[1]	C	N[1]
Railroad tracks and limited access highways	B	B	B	B	B	B
Constant potential supply conductors						
0 to 750 V open or cable	N[1]	N[1]	C	N[1]	C[2]	C[4]
750 V to 8.7 kV						
Open	C	N[1]	C	N[1]	C[2]	N[1]
Cable	N[1]	N[1]	C	N[1]	C[2]	N[1]
Exceeding 8.7 kV						
Open	B	C	B	N[1]	C[2]	N[1]
Cable	C	N[1]	C	N[1]	C[2]	N[1]
Communication conductor: Open or cable	N[1]	N[1]	B[3]	B[3]	B[3]	B[3, 4]

[1]Grade N construction is not applicable to systems of REA borrowers. For lines to satisfy requirements of REA Bulletin 40-7, where the table lists Grade N, substitute Grade C.

[2]Supply conductors shall meet the requirements of grade B construction if the supply circuits will not be promptly de-energized, both initially and following subsequent breaker operations, in the event of a contact with lower supply conductors or other grounded objects.

[3]The supply conductors need only meet the requirements of grade C crossing construction if both of the following conditions are fulfilled: a) The supply voltage will be promptly removed from the communication plant by de-energization or other means, both initially and following subsequent circuit breaker operations in the event of a contact with the communication plant, b) The voltage and current impressed on the communication plant in the event of a contact with the supply conductors are not in excess of the safe operating limit of the communication protective devices.

[4]On systems of REA borrowers, grade C construction may be used over not more than one twisted pair or parallel-lay communication conductor or communication service drops. Grade C construction may also be used if crossing over supply services only. Increased overload capacity factors for grade C crossing construction are not required for these crossings.

For other exceptions, see NESC TABLE 242-1.

overload capacity factors for wood pole construction are listed in Table II-11 of Chapter II-11. Where Table II-9 lists a Grade C crossing, use the "crossing" overload capacity factor. Where the table lists a Grade N crossing, use the "elsewhere" overload capacity factor.

The several parts of a pole structure (including pole, crossarms, pins, and insulators) may comply with several different grades of construction when the structure supports several conductors with differing grades of construction. Those parts of the structure, i.e. crossarms, which support only conductors of one grade, need only meet strength requirements of that grade. Those parts of the structure which support conductors of more than one grade must meet strength requirements of the highest grade conductor supported by that part. Therefore, the pole and any supporting guys attached to the pole must meet the strength requirements of the highest grade of conductor supported by the pole.

CHAPTER II-10
LOADING REQUIREMENTS

A. NESC SECTION 25 - LOADING REQUIREMENTS

Rules concerning loading requirements for overhead lines are covered by Section 25 of the NESC.

The strength that must be designed into a distribution line depends to a large extent on the wind and ice loads that may be imposed on the conductors and supporting structures. These loadings vary with location of the lines, but are generally related to the geographical location of the line.

The NESC provides general loading requirements which apply to all conductors and supporting structures, and extreme wind loading requirements which apply to selected tall structures and high conductor elevations. When both requirements apply, the required loading should be that which when combined with the appropriate overload capacity factors, has the greatest effect on strength requirements.

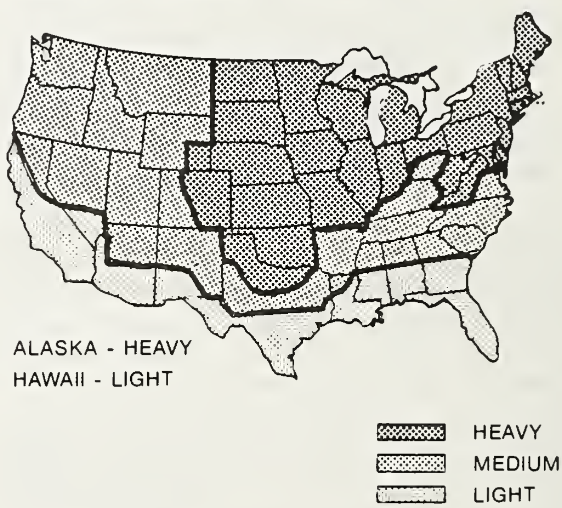
B. NESC RULE 250B -GENERAL LOADING

The NESC divides the country into geographic weather zones which are designated as loading districts and are classified as heavy, medium, and light. Figure II-8 shows a map which identifies the location of these loading districts. Table II-10 shows the minimum radial thickness of ice, the wind pressure to be used in calculating loadings, and the temperature at which the loads are to be applied.

C. NESC RULE 250C - EXTREME WIND LOADING

The 1977 NESC added an extreme wind loading requirement. While this requirement, as written, applies to tall poles used mostly in transmission lines, the rule also applies to distribution lines where any portion of a structure or supported facilities (including conductors) is located in excess of 18.3 m (60 ft.) above ground or water level. For distribution lines, such cases are infrequent, but can occur at line crossings over ravines, streams, waterways, and deep railroad and highway cuts.

Figure II-9 is a map of the United States which shows isotach lines which represent the minimum horizontal wind pressures to be used for calculating loads on tall poles and high conductors. The figure also provides metric and customary wind pressure and velocities for the isotach lines. For wind pressure at a specific location, use a value not less than that of the nearest wind pressure line.



GENERAL LOADING MAP OF UNITED STATES WITH RESPECT TO LOADING OF OVERHEAD LINES

FIGURE II-8

TABLE II-10
ICE, WIND AND TEMPERATURE FOR LOADING DISTRICTS
(Adapted from NESC Table 250-1)

	Loading Districts (For use with Rule 250B)			Extreme Wind Loading (For use with Rule 250C)
	Heavy	Medium	Light	
Radial thickness of ice	12.7 mm (0.5 in)	6.35 mm (0.25 in)	0	0
Horizontal wind pressure	190 Pa[4 lb/ft²]	190 Pa [4 lb/ft²]	430 Pa [9lb/ft²]	Fig. II-9
Temperature	-20°C [0°F]	-10°C [15°F]	0°C [30°F]	15°C [60°F]

While not required by NESC, the extreme wind map has another design value. It is possible in certain areas for lines in open or exposed locations to be subjected to wind loading exceeding the Grade C design strengths of structures. Experience with the performance of lines in a given area should be used as a guide in determining if lines, regardless of height of poles or conductors, should be designed for extreme loading requirements where such loading is in excess of Grade C strength requirements.

D. NESC RULES 251 AND 252 - APPLICATION OF LOADS

NESC Rules 251 and 252 describe the methods of determining and applying vertical, transverse, and longitudinal loads to the supporting structures.

The rules are quite clear and the application is demonstrated in Parts III, IV, V, and VI of this design manual.

ISOTACH LINE NUMBER	PRESSURE Pa	PRESSURE lb/ft²	VELOCITY m/sec	VELOCITY km/hr	VELOCITY mi/hr
1	190	4	17.9	64	40
2	290	6	21.9	79	49
3	430	9	26.8	97	60
4	620	13	31.3	113	70
5	770	16	35.8	129	80
6	1000	21	40.2	145	90
7	1240	26	44.7	161	100
8	1480	31	49.2	177	110
9	1720	36	53.6	193	120

EXTREME WIND LOADING MAP

FIGURE II-9

CHAPTER II-11
STRENGTH REQUIREMENTS

A. NESC SECTION 26 - STRENGTH REQUIREMENTS

Section 26 of the NESC establishes overhead line strength requirements for specific grades of construction and loading requirements. This chapter covers only those strength requirements peculiar to the components and overall strength of Grade B and C wood pole distribution lines.

The entire Section 26 was rewritten for the 1977 NESC. Minor revisions were made in the 1981 NESC.

For distribution line design, there are very few actual changes in strength requirements. The principal changes of interest to distribution lines discussed herein include:

- New methods of designating safety factors;
- Increased strength requirements for guys;
- Column strength of guyed structures;
- Additional strength requirements for tall poles and high conductors subject to extreme winds.

B. OVERLOAD CAPACITY FACTORS

The most conspicuous change in the 1977 NESC concerning strength requirements for distribution structures was the method of representing margins of safety for structures. Historically, for steel structures these margins have been represented as "overload capacity factors," while for wood and concrete poles and guyed structures the margins were represented as percents of ultimate strength or percents of ultimate fiber stress. The latter method has been confusing, particularly in angle structures where part of the applied load utilized one percentage of strength and another part of the load utilized another percentage of strength.

In the current NESC, the safety margins are applied to the loads imposed on the structures rather than to the structural members.

The NESC now uses "overload capacity factors" to define essentially all margins of safety for structure design. Percentage of rated breaking strength is retained to identify various loading limits for cables including conductors, messengers, guy strand, etc.

The following illustrates the change in margin of safety methods. In the 1973 NESC for wood pole design, Grade C construction was defined as not exceeding 50 percent of the allowable stress of the pole to withstand the vertical and transverse loads as defined by the code.

In the 1977 NESC, Grade C construction was defined as design to withstand the transverse and vertical loads in Rule 250 (formerly Rule 251), multiplied by an overload capacity factor of 2.0 without exceeding the designated fiber stress.

In this example, the two methods provide the same result. The margin of safety in one method is the reciprocal of that of the other method. In making computations, it is simply a matter of determining whether the margin of safety is multiplier or divider.

This pattern of shifting the old code margin of safety (percent of ultimate strength) from the structure component to an "overload capacity factor" applied to the structure loading is generally consistent throughout Section 26 for wood pole distribution lines.

The overload capacity factors given hereafter in this chapter apply for the combined ice and wind loading conditions specified in NESC Rule 250B for the heavy, medium, and light loading districts.

For the extreme wind loading conditions specified in NESC Rule 250C, an overload capacity factor of not less than 1.0 shall be applied for structures and 1.25 for other supported facilities.

C. NESC RULE 261A2 - STRENGTH OF WOOD STRUCTURES

The overload capacity factors for Grades B and C wood structures are provided in Table II-11 which follows and is adapted from NESC Table 261-3.

The application of overload capacity factors of Table II-11 is subject to the following general rules:

- Wood structures shall be designed to withstand the transverse, vertical, longitudinal, and dead-end loadings in Rule 252 multiplied by the appropriate overload capacity factors without exceeding the designated fiber stress of the wood.
- The designated fiber stress for natural wood poles shall be as given by ANSI 05.1,

TABLE II-11

OVERLOAD CAPACITY FACTORS FOR WOOD STRUCTURES WHEN INSTALLED

(Adapted from NESC Table 261-3)

	Grade B	Grade C	Extreme Wind
Transverse (wind) and vertical strength			
At Crossings	4.0	2.67	1.0
Elsewhere	4.0	2.00	1.0
Transverse (wire tension load) strength			
At Crossings	2.0	1.33	1.0
Elsewhere	2.0	1.33	1.0
Longitudinal strength			
In general	1.33	no requirement	1.0
At dead ends	2.00	1.33	1.0

Specifications and Dimensions for Wood Poles. The 1981 NESC references the 1978 edition of ANSI 05.1.

- Wood poles acting as single-based structures shall meet these requirements without exceeding the designated fiber stress at the ground line or at the point of guy attachment for guyed poles.
- At an angle in the line, the wood structure shall be designed to withstand the total transverse loading (wind and tension) of NESC Rule 252 multiplied by the appropriate overload capacity factors.
- Guyed poles shall be designed as columns, resisting the vertical component of guy tension plus all other vertical loads on the structure. The NESC does not provide a method for determining minimum column strength. A guide for this requirement is provided in Part V of this design manual.

Detailed application of these rules is demonstrated in Parts V and VI of this design manual.

D. STRENGTH REQUIREMENTS AT CROSSINGS

The strengths of Grades B and C supporting structures at crossings shall be as required for the grade of construction of the supply conductors supported at the crossing. Refer to NESC Table 242-1 or Table II-9 in Chapter II-9.

Single based wood pole structures with conductor supports in conformance with REA standard drawings are subject to the following strength requirements.

Rural distribution lines constructed to Grade B strength requirements will generally meet all crossing requirements provided double arm assemblies, such as the REA C2-assembly, are used at Grade B crossings.

The following requirements apply to rural distribution lines constructed to Grade C strength requirements:

1. Grade C Crossings

Lines designed to minimum requirements of Grade C require an increase in transverse strength for wind at Grade C crossings. Overload capacity factors for Grade C crossings are provided in Table II-11.

However, on systems of REA borrowers the increase in strength is not required for lines constructed to Grade C construction, where the NESC requires only Grade N construction.

2. Grade B Crossings

Lines designed to Grade C requirements must be upgraded to Grade B requirements at Grade B crossings. Special rules are provided which permit changing the grade without separating the grades of construction by dead-ending:

- The longitudinal strength for the Grade B crossing may be met by placing a supporting

structure at either end of the span with the required longitudinal strength for Grade B.

- If the structure is a flexible structure, such as wood, so that the clearance of the crossing span can be affected, it may be necessary to increase the normal clearance or to provide head guys to prevent such deflection. It should be noted that some railroads require that guys be provided for such crossings.
- When impractical to install the longitudinal strength at the crossing structure, the strong structure may be located one or more spans away, but not more than 150 meters [500 ft] away and not more than 245 meters [800 ft] between the two strong structures provided the line between the longitudinally strong structures meets the higher grade requirements as to transverse strength and stringing of conductors.

E. NESC RULE 261D - STRENGTH REQUIREMENTS FOR GUYED STRUCTURES

The overload capacity for guys and guy anchors are provided in Table II-12, which has been adapted from NESC Table 261-5.

TABLE II-12

OVERLOAD CAPACITY FACTORS FOR GUYS

(Adapted from NESC Table 261-5)

	Overload Capacity Factors	
	Grade B	Grade C
Transverse strength		
Wind load	2.67	2.00
Wire tension load	1.50	1.15
Longitudinal strength (except at angles)		
In general	1.00	no requirement
At dead ends	1.50	1.15

When guys are used with wood structures to meet the strength requirements for the structure, they shall be considered as taking the entire load in the direction they act, the pole acting as a strut only.

The guys shall be of strength to withstand the loads in Rule 252 multiplied by the overload capacity factors of Table II-11 without exceeding 90 percent of the rated breaking strength of the guy.

At line angles the guy must hold the total transverse load including both wind loads and conductor tension loads multiplied by the applicable overload capacity factors.

The above requirement for guys to be capable of withstanding the loads without exceeding 90 percent of rated strength of the guy was a new requirement added by the 1977 NESC. Guy tables, charts, and other guides prepared prior to 1977 were voided by this rule change.

The application of these requirements is demonstrated in Parts V and VI of this design manual.

F. NESC RULE 261D - STRENGTH OF CROSSARMS

Crossarm assemblies shall be capable of withstanding the vertical loads of NESC Rule 252 without exceeding 50 percent of the designated fiber stress. They shall withstand the longitudinal loads without exceeding the designated fiber stress.

NESC Rule 261D provides additional requirements not covered here. REA standard construction drawings for distribution pole top assemblies are designed to satisfy the requirements of the NESC when used for normal applications for which the drawing was intended. Part III of this design manual provides guides covering vertical and longitudinal strength capabilities of the REA standard construction drawing units.

G. NESC RULE 277 - MECHANICAL STRENGTH OF INSULATORS

Insulators shall withstand all loads specified in NESC Section 25, except those for extreme wind loading, without exceeding the following percentage of their rated ultimate strength.

Cantilever: 40 percent

Compression: 50 percent

Tension: 50 percent

The rated ultimate strength of suspension type insulators is considered to be the "combined mechanical and electrical strength."

PART III
REA SYSTEM OF UNIT CONSTRUCTION AND STANDARD CONSTRUCTION DRAWINGS

INTRODUCTION

During the staking of the line, the staking engineer specifies the construction assemblies that are to be installed at each structure location. The construction units used for this purpose and the preparation of staking sheets are described in various REA contract forms, in REA standard specifications, and in REA construction drawings.

The REA construction drawings are graphic representations of the construction unit assemblies. The drawings show the dimensions and configuration of the assembly. The materials are further defined in REA Bulletin 43-5, List of Materials Acceptable for Use on Systems of REA Electrification Borrowers. Bulletin 43-5, in turn, references applicable industry standards and REA standard specifications. Thus, the drawings together with the supporting data, provide a basis for determining the strength capability of the construction assembly. The REA construction drawings provide another important basis for the determination of the design criteria and preparation of staking design data for the design of an overhead distribution line.

This part of this design manual discusses the unit system, the structural and design limitations of construction units, and the application of REA standard construction units.

CHAPTER III-1
REA UNIT SYSTEM OF CONSTRUCTION

A. PURPOSE OF CONSTRUCTION UNITS

Distribution systems are generally discussed in terms of kilometers or miles of line, the number of phase conductors, and the number of consumers or load density. However, no two individual line sections of a distribution system will be found to be exactly alike.

In order to provide a detailed description of a line section for purpose of construction, for maintaining a record of plant inventory, for ordering materials, etc., it is necessary for any distribution utility to break the system components down into definable and measurable construction units.

Early in the rural electrification program, REA, as an aid to its borrowers, established a universal system of construction units for use on these systems. The use of this system continues to be of considerable benefit, not only in the staking of the line, but also in the development of the design criteria and staking design guides for the line.

B. CATEGORIES OF CONSTRUCTION UNITS

The basic categories of REA standard units for new construction are:

- **A Pole Top Assembly Unit** (A, B, or C units) consists of the material required to support the primary conductors. It does not include the pole.
- **A Conductor Assembly Unit** (D units) consists of 304.8 meters or 1,000 feet of conductor or cable for primaries, secondaries, or services and includes tie wires, splicing sleeves, connectors, and necessary armor.
- **A Guy Assembly Unit** (E units) consists of guy strand and necessary hardware.
- **An Anchor Assembly Unit** (F units) consists of the anchor with rod.
- **A Transformer Assembly Unit** (G units) consists of the transformer, its protective equipment, its hardware and leads with their connectors, and support insulators and pins.
- **A Secondary Assembly Unit** (J units) consists of the hardware and insulators needed to support the secondary conductors.

- **A Service Assembly Unit** (K units) consists of the hardware and insulators required to support the service conductors or cable.
- **A Miscellaneous Unit** (M units) consists of any additional unit not described above.
- **A Rights-of-Way Clearing Unit** (R units) is a cleared section of land, 304.8 meters or 1,000 feet in length to a designated width.

Pole top assembly units are subdivided into A, B, and C units:

- **A Units** designate assemblies for use on single-phase circuits.
- **B Units** designate assemblies for use on V-phase circuits.
- **C Units** designate assemblies for use on three-phase circuits.

The pole top assembly units (A, B or C units) are further subdivided into primary voltage categories by the use of prefix letters as follows:

- **A, B, or C** (no prefix letter) designates a primary pole top assembly for use on a 12.5/7.2 kV voltage class circuit.
- **VA, VB, or VC** designates a primary pole top assembly for use on a 24.9/14.4 kV voltage class circuit.
- **ZA, ZB, ZC** designates a primary pole top assembly for use on a 34.5/19.9 kV voltage class circuit.

C. APPLICATION OF CONSTRUCTION UNITS

Staking is performed and staking sheets are prepared in such a manner that, upon the completion of the staking, any section of line may be listed in terms of types and quantities of construction units.

The tabulation of construction units from the staking sheets is used to define the detailed scope of work in a construction contract.

A complete description of construction units is given in the construction contract documents which also include by reference the construction drawings. The construction drawings show the physical arrangement of the construction units as assembled on the pole.

In connection with the issuance of invitations to bid on a project, contractors are furnished with a set of plans and specifications for the work. The plans and specifications list the quantities and types of the various construction units which will be required to effect the completion of the project. The bidder inserts the bid prices for each of the construction units listed, computes the arithmetical extensions, and shows the total dollar amount of the overall bid for the project. The set of plans and specifications which constitute the bidder's original proposal, when properly executed, serves as the construction contract for the project.

The engineer supervises the construction of the project and inspects all materials prior to installation. Any items of material or any construction units which are not in accordance with the specifications or which do not meet the required standards of workmanship are rejected by the engineer.

Upon the completion of the project, the engineer makes a final inspection of the contractor's work, tabulates the construction units installed by the contractor, and proceeds with the preparation of the final documents to close out the contract.

CHAPTER III-2
METRICATION OF CONSTRUCTION ASSEMBLIES

A. IMPACT OF METRICATION ON CONSTRUCTION ASSEMBLIES

This edition of this design manual anticipates that the electric utility industry will continue to progress in the conversion from the U.S. customary system of units to the SI metric system of units. In the U.S., this conversion is a voluntary action. There is no specific date when all new materials and all material and design standards must be converted to the metric system.

To facilitate the conversion process, all new or reissued standards prepared under the auspices of the American National Standards Institute (ANSI), American Society for Testing Materials (ASTM), and the Federal agencies of the U.S., are required to be based on the metric system of units, unless good cause can be shown for defer-

ment. The current edition of the NESC was based on the customary system of units by the privilege of deferment. It is probable that the next edition of the NESC will be based on the metric system. It is also anticipated that the next editions of standards for poles, crossarms, and other line materials will be metricated.

Not all standards will be converted simultaneously. Neither will all manufacturing industries, nor all manufacturers within an industry, convert at one time. Some conversions of materials will be soft conversions and some will be hard conversions. Refer to Appendix A for a discussion of conversion methods.

It is anticipated this conversion period will create some problems in the construction of pole line assembly units. Some construction drawings will be based on customary units and some on metric units. In either case, some materials will be based on metric dimensions and some on customary dimensions, thus it is quite probable that in actual practice it may be necessary to construct hybrid assembly units.

In some cases, it may be advisable for the engineer to provide the construction staff with temporary "marked-up" versions of construction drawings, based on materials actually available for construction. This will be most needed when field drilling of poles or members, or for other modifications required to accommodate available materials.

CHAPTER III-3
REA STANDARD OVERHEAD DISTRIBUTION CONSTRUCTION DRAWINGS

A. REA STANDARD CONSTRUCTION DRAWINGS

The great majority of the REA standard units of construction are defined with the aid of REA standard construction drawings which show in detail the dimensions and list the materials used in the construction and assembly of the units. The drawings are prepared in accordance with the unit system discussed in the previous chapter. For the convenience of the user, all of the drawings of assembly units commonly used in the construction of a line of a specific primary voltage class have been packaged in the following REA forms:

- **REA Form 801,** Specifications and Drawings for 34.5/19.9 kV Line Construction.
- **REA Form 803,** Specifications and Drawings for 24.9/14.4 kV Line Construction.
- **REA Form 804,** Specifications and Drawings for 12.5/7.2 kV Line Construction.

B. DESCRIPTION OF DRAWINGS

Each construction drawing consists of one unit installed in place. Other components of the structure which are not part of the unit but are necessary for clarity are shown by dotted lines. In addition to drawings that are construction units, guide drawings are provided which show the assembly of two or more construction units or the use of a construction unit under various situations. These guide drawings are not construction units.

C. DEVELOPMENT OF ASSEMBLIES

The construction assemblies shown on the standard drawings have been developed to meet the special needs of rural line construction. They are based on the following considerations:

- Adequate separation distance between conductors to permit long spans without conductor slap;
- High impulse strength for the outer phases by the use of wood crossarm and crossarm braces;
- Minimum radio and TV interference is achieved by providing generous separation distances between hardware associated with energized conductors and ground;
- Clearances to meet NESC requirements for climbing and working space, vertical jumpers, and conductor supports;
- Generous clearances to permit safe hot line work. Long pole top pins and extension links on dead-end conductors in work areas are two ways in which increased clearances are provided;
- Positive identification of the neutral conductor;
- Future conversion of single-phase and V-phase lines to three-phase lines without extensive rearrangement of the pole top. The initial staking of the line must, of course, permit such conversion;
- Sufficient pole top assemblies are provided to meet most conditions likely to be encountered in service.

D. SELECTION OF MATERIALS

The construction assemblies shown on the standard drawings have been developed using commonly available materials. So far as practical, the number of sizes of similar materials has been held to a minimum to facilitate purchasing and warehousing of materials and to simplify construction.

As an aid in selecting and purchasing materials for construction of the standard assemblies, materials of various manufacturers which have demonstrated conformance with the requirements of the standard construction assemblies are identified and listed by item letter identifier in REA Bulletin 43-5, List of Materials Acceptable for Use on Systems of REA Electrification Borrowers.

E. EXAMPLES OF STANDARD CONSTRUCTION DRAWINGS

Figures III-1, 2, 3, and 4 show typical examples of REA construction drawings. The examples are from REA Form 803, Specifications and Drawings for 24.9/14.4 kV Line Construction.

CHAPTER III-4
POLE TOP CLEARANCE LIMITS

A. DIMENSIONS OF POLE TOP ASSEMBLIES

The configurations and dimensions of the various pole top assemblies are of importance in determining several NESC clearance requirements. While the assemblies are designed with adequate separation for reasonable long spans, there are limitations to the span lengths which should be determined and included as a design guide for the staker.

While the dimensions of similar pole top assemblies are often nearly equal, differences do occur. Clearances should be calculated using the specific dimensions shown on the construction drawing for the selected pole top assembly.

B. LINE-TO-GROUND CLEARANCES

The configuration and dimensions of the basic pole top assembly will determine whether the neutral conductor, phase conductor, or both will limit the span for a given pole height. Calculation methods for determining line-to-ground clearances and preparation of staking tables are discussed in Part V of this design manual.

C. CLEARANCES BETWEEN CONDUCTORS CARRIED ON SAME SUPPORTS

All of the pole top assemblies shown on REA standard drawings have more than adequate conductor separation at the support. What is of more concern is the configuration and conductor separations at all points between two supports.

At any point in the conductor span between two pole top assemblies the following should be considered:

- Any two conductors at the same elevation should meet horizontal clearance requirements;
- Any conductor directly above another should satisfy vertical clearance requirements;
- Any other two conductors should meet diagonal clearance requirements.

The NESC requirements for the horizontal, vertical, and diagonal separations for the conductors supported by the pole top assemblies are discussed in Chapter II-7 of this design manual.

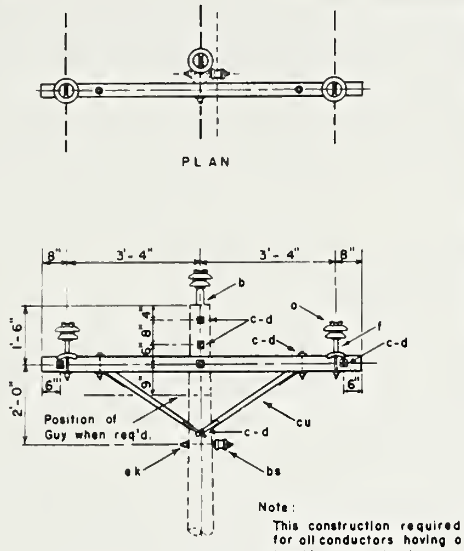
1. Pole Top Assemblies of Like Configuration

When the span conductors are supported by two pole top assemblies which have identical configurations and dimensions, it is assumed the phase conductors will maintain this configuration throughout the span. There may be a maximum allowable span due to horizontal clearance requirements based on conductor sag. Although this maximum span limitation will be quite long, it should be determined.

If any one of the phase conductors is located so the vertical or diagonal clearance to the neutral conductor or any other underbuild conductor is a factor, this clearance requirement may be the most limiting.

2. Pole Top Assemblies of Unlike Configuration

When the span conductors are supported by two pole top assemblies of unlike configuration, e.g., type C1 and C4 assemblies, the configuration changes in the span and the dimensions between the conductors may be less or more



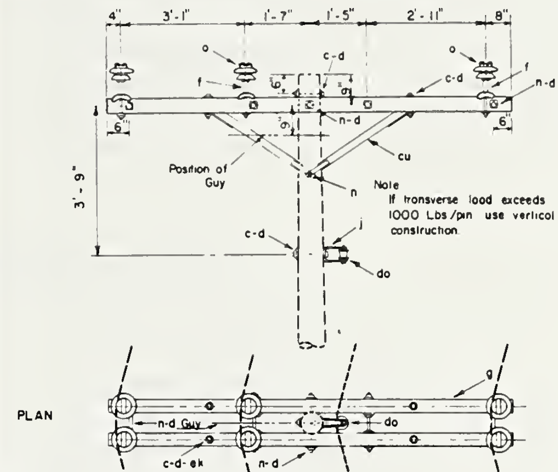
Note:
This construction required for all conductors having a breaking strength of more than 4500 pounds

ITEM	NO.	MATERIAL	ITEM	NO.	MATERIAL
a	3	Insulator, pin type	f	2	Pin, crossarm, clamp type
b	1	Pin, pole top, 20"	g	1	Crossarm, 3 3/4" x 4 3/4" x 8'-0"
c	2	Bolt, machine, 1/2" x req'd length	bs	1	Bolt, single upset, insulated
c	6	Bolt, machine, 5/8" x req'd length	cu	1	Brace, wood, 60" span
d	2	Washer, round, 1 3/8" dia	ek		Locknuts
d	10	Washer, square, 2 1/4"			

14.4 / 24.9 KV.
3-PHASE CROSSARM CONSTRUCTION- 0° TO 2° ANGLE
(LARGE CONDUCTORS)

FIGURE III-1

VC1-2



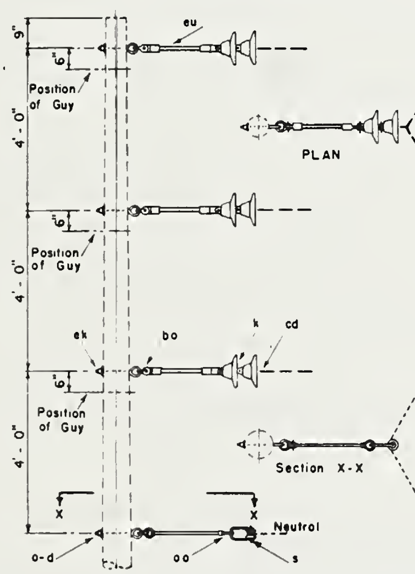
Notes
1. Side groove of insulator must always be larger than the overall diameter of conductor including armor rods when required
2 Center phase wire or neutral wire may be located on the opposite side of the pole where necessary to avoid crossing of wires in midspan.
3. This construction required for all conductors having a breaking strength of more than 4,500 pounds

ITEM	NO	MATERIAL	ITEM	NO	MATERIAL
a	6	Insulator, pin type	g	2	Crossarm, 3 3/4" x 4 3/4" x 10'-0"
c	2	Bolt, machine, 5/8" x req'd length	j	2	Screw, lag, 1/2" x 4"
c	4	Bolt, machine, 1/2" x req'd length	n	6	Bolt, double arming, 5/8" x req'd length
d	21	Washer, square 2 1/4"	cu	2	Brace, wood, 60" span
d	4	Washer, rd, 1 3/8" diam.	do	1	Bracket, insulated
f	6	Pin, crossarm, steel, clamp type	ek		Locknuts

144/249 KV, 3-PHASE
CROSSARM CONSTRUCTION- DOUBLE PRIMARY SUPPORT
(LARGE CONDUCTORS)
MAXIMUM TRANSVERSE LOADING— 1000 LBS./PIN

FIGURE III-2

VC2-2

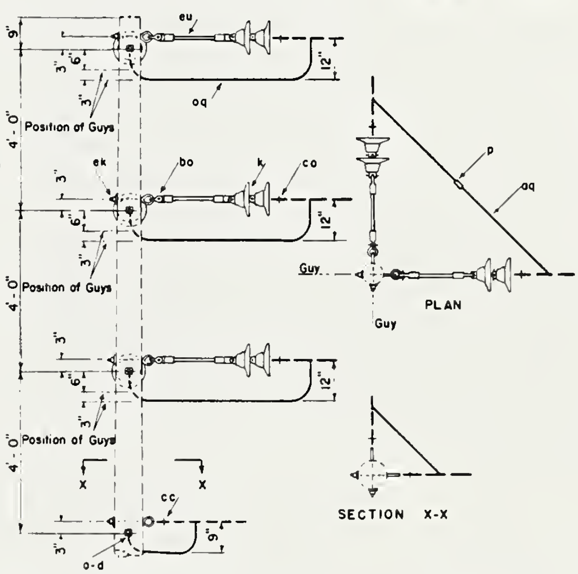


ITEM	NO	MATERIAL	ITEM	NO	MATERIAL
d	4	Washer, square, 2 1/4"	bo	4	Shackle, anchor
k	6	Insulator, suspension, 10"	cd	3	Angle assembly, primary
o	5	Bolt, eye, 5/8" x required length	ek		Locknuts
s	1	Clevis, secondary, swinging, insulated	eu	3	Link, extension, insulated
oo	1	Nut, eye, 5/8"			

144/249 KV - THREE PHASE
VERTICAL CONSTRUCTION, 30° TO 60° ANGLE
LARGE CONDUCTORS

FIGURE III-3

VC3 L



ITEM	NO.	MATERIAL	ITEM	NO.	MATERIAL
d	8	Washer, Square, 2 1/4"	ca	6	Deadend assembly, primary
k	12	Insulator, suspension, 10"	cc	2	Deadend assembly, neutral
o	8	Bolt, eye, 5/8" x required length	ek		Locknuts
p		Connectors, as required	eu	6	Link, extension, insulated
aq		Jumpers, as required			
bo	6	Shackle, anchor			

144/249 KV - THREE PHASE
VERTICAL CONSTRUCTION, 60° To 90° ANGLE
LARGE CONDUCTORS

FIGURE III-4

VC4 - 1L

restrictive than at the supporting assemblies. This problem becomes even more sensitive when the sags of the various conductors differ.

In some cases the maximum allowable spans between such structures may be less than the basic average span of the line. It is important that the maximum allowable spans be calculated and included in the staking guide for all anticipated combinations.

Methods for calculation of these maximum allowable spans are given in Chapter V-5.

CHAPTER III-5
LOADS ON POLE TOP ASSEMBLIES

A. CATEGORIES OF LOADS

Much of the design criteria for the rural distribution line is related to the loads imposed on the supporting structures by the primary circuit conductors and the capability of the structure to withstand these loads. It is, therefore, important to understand the nature of the loads which are applied to the pole top assembly and the capabilities of the various types of assemblies to withstand these loads. The loads applied to the structure are identified as being vertical, transverse, and longitudinal with the latter two being in the horizontal plane.

B. VERTICAL LOADS

Vertical loads are loads applied down on the structure and consist of the weight of the loaded conductors supported by the structure. The span length of conductor supported will vary with conductor temperature and loading and is measured from the low point of sag in one direction from the structure to the low point of sag in the other direction. This is called the vertical span or weight span of the structure.

The loads of interest are those which the members and components of the assembly must transfer to the supporting pole. The limiting loads are generally the cantilever loads applied to crossarms and other types of supports including insulators installed in a position other than vertical.

In distribution line design the weights of pole top assembly members and insulators are usually ignored.

C. TRANSVERSE LOADS

Transverse loads are horizontal loads applied perpendicular to the line or at an angle structure applied in the direction of the bisector of the angle. The loads consist of the wind load on the conductor, and at angles it also includes the component of conductor tension in line with the bisector of the angle. The span length of supported conductor is from midspan to midspan and is called the horizontal span or wind span.

For tangent and small angle structures, the limiting loads are generally cantilever loads applied to the insulator assemblies. For large angle structures where the conductors are supported with suspension type insulator assemblies, the limiting loads are the tension loads applied to the insulator assembly. For distribution line design, wind loads on the components of the pole top assembly are usually ignored.

D. LONGITUDINAL LOADS

Longitudinal loads are horizontal loads applied in line with the pole line. They generally consist of the unbalanced conductor tension loads applied to the structure, and at dead-ends consist of the entire horizontal component of conductor tension.

The loads are limited by the tension strength of the insulator assembly and capability of assembly members to withstand cantilever loads. The latter limiting condition is a factor only when the conductor is dead-ended on an arm assembly rather than on the pole.

In distribution line design, it is common practice to use the average conductor tension as found on sag-tension tables rather than determining the horizontal tension.

E. POLE TOP CATEGORIES BASED ON CONDUCTOR SIZE

The pole top assembles shown on REA standard construction drawings are categorized by the size and strength of conductors for which they are suited.

1. Small Conductor Assemblies

Drawings which are not otherwise identified are for normal use with small conductors.

Generally these assemblies can be used to meet Grade C construction limits without additional strength calculations when used within the limits given on the drawing. If small angle structures are to be used for relatively long spans, it may be desirable to provide a pin loading guide.

2. Large Conductor Assemblies

Drawings, which are identified as suitable for large conductors, can generally be used without additional strength calculations when used within the limits given on the drawing. It is generally advisable to provide a pin loading guide for use in staking such lines.

When these drawings are used with extra long spans and/or extra large conductors, design guides based on pin strength, crossarm strength, and insulator strength should be provided.

3. Conductor Size Categories

Conductors are categorized as follows:

- **Small Conductors** are defined as those with a rated breaking strength of less than 20 000 N [4500 lb.], e.g. No. 1/0 ACSR and smaller.
- **Large Conductors** are defined as those with a rated breaking strength from 20 000 N [4500 lb.] to 45 000 N [10 000 lb.], e.g. No. 2/0 ACSR to No. 4/0 ACSR or 334.4 kcmil (18/1) ACSR.
- **Extra Large Conductors** are defined as those with a breaking strength greater than 45 000 N [10 000 lb.], e.g., 266.8 kcmil (26/7) ACSR and larger. Extra large conductors are those with a rated strength which exceeds the rated M&E strength of the standard ANSI 52-1, 6 inch suspension insulator.

Large conductor pole top assemblies can be used for extra large conductors provided the conductor design tension and maximum spans are coordinated with the strength limitations of the structures and structure components.

F. POLE TOP CATEGORIES BASED ON USE

The pole top assemblies shown on REA standard construction drawings can be categorized by the use to be made of the structure on which the pole top assembly is installed. The structure uses fall into the following five categories.

1. Small Angle Assemblies

Small angle pole top assemblies are basically designed for use on tangent type structures. They are designed to withstand the vertical and transverse loads imposed by the conductors. The inherent strength in the longitudinal direction is normally sufficient to withstand the longitudinal unbalance that may be imposed on the structure. Because of the transverse strength of the assembly, it can be used for small angles by reducing the permissible horizontal span length. The construction drawings are usually given a nominal range of permissible angle ranges. The actual range will vary with conductor size, tension, and wind span as limited by the strength of the pole top assembly, pole, and/or guy assembly used.

2. Medium Angle Assemblies

The medium angle pole top assemblies are similar in conductor position configuration to the small angle structures. As the angle increases, the pole strength can be increased by proper guying, and the transverse loading on the small angle assembly becomes limiting. For the medium angle structures, the transverse capabilities are increased by strengthening the conductor supports, e.g., the insulator assemblies. The construction drawings usually give a nominal range of permissible angles. Again the actual range will depend on the conductor size, tension, and wind span as limited by the transverse strength of the pole top assembly.

3. Large Angle Assemblies — Running Corners

The large angle, running corner assembly usually has a vertical conductor configuration with the conductor supported by a single suspension insulator string assembly. The strings are attached directly to the pole which is supported by a bisector guy assembly. The structure is used where the transverse load is too great to be supported by insulator pin or post type insulator assemblies. The nominal range of permissible angles is usually given on the construction drawings. The actual range will depend on conductor size, tension, and wind span as limited by the strength of the insulator assembly.

4. Large Angle Assemblies — Dead-ended

The large angle, double dead-ended assembly usually has a vertical conductor configuration. A double dead-end crossarm assembly can be used. The dead-end insulator strings are attached directly to the pole or arms. In determining the strength of the assembly, it is usual to treat each of the two dead-ends as an independent dead-end assembly.

5. Dead-end Assemblies

The dead-end assembly may have either a vertical conductor configuration with the insulator assemblies attached directly to the poles or a horizontal configuration with the insulator assemblies attached directly to the crossarms. Where possible, attachment to the pole is preferred for both strength and economic considerations. Where conductors are dead-ended on arms, bridle guying is preferred. The strength of the assembly is limited by the longitudinal strength of the insulator assembly and, when crossarms are used, most likely by the longitudinal strength of the arm assembly.

CHAPTER III-6
STRENGTH OF POLE TOP ASSEMBLY COMPONENTS

A. DETERMINATION OF LOADING LIMITS

While there are many pole top assemblies shown on the construction drawings, the strength capabilities of these assemblies can be determined by relatively few components or subassemblies.

For pole top assemblies shown on REA standard drawings, the strength capabilities can be determined by the following:

- **Vertical loading limits** can be determined from the allowable resisting moments of the standard crossarms.
- **Transverse loading limits for small and medium angle assemblies** can be determined from the strength capabilities of the several standard pin and post type insulator assemblies and wood supporting members.
- **Transverse loading limits for large angle assemblies** can be determined by the permissible tension of the suspension insulator support assembly.
- **Longitudinal loading limits for dead-end assemblies** can be determined by the permissible tension of the suspension insulator assembly and/or allowable resisting moment of the standard crossarms.

The following sections provide data concerning the strength capabilities of these components.

B. STRENGTH OF CROSSARMS

The method for determining the allowable load which can be placed on a crossarm is the same whether the load is applied vertically or longitudinally. The allowable resisting moment of the arm should be capable of withstanding the sum of the moment loads applied to the arm. Since the arms are standard dimension, the resisting moments in the vertical and horizontal planes are fixed. The moment arms for the standard assemblies are also generally fixed. Therefore the permissible loads are calculated. If the capability of the arm is insufficient, a larger size arm is tried or more than one arm used to carry the load. The basic equation is as follows:

$$M_W = F_O[(W)\ (B)] \qquad \text{EQ III-6A}$$

Where:

M_W = Moment applied to the crossarm
W = Weight or force of the load
B = Moment arm at which W is applied
F_O = NESC overload capacity factor

Where there is more than one load:

$$[(W)(B)] = (W_1)(B_1) + (W_2)(B_2) + \ldots + (W_n)(B_m)$$

1. Dead-end Crossarm Calculations

If it is assumed that all conductors to be dead-ended on the critical one-half of the arm will be of the same tension, the maximum allowable conductor tension can be determined as follows:

$$W_h = \frac{(N)\ (M_h)}{(F_O)\ (B_m)} \qquad \text{EQ III-6B}$$

Where:

M_h = Maximum allowable moment of the crossarm in the horizonal plane
W_h = Maximum allowable conductor tension
N = Number of crossarms
F_O = NESC overload capacity factor
B_m = Summation of conductor moment arms
$B_m = B_1 + B_2 + \ldots + B_m$

2. Vertical Span Calculations

If it is assumed conductors supported on the critical side of the crossarm are of the same weight per unit length, the allowable vertical span can be determined as follows:

$$S_V = \frac{(N)\ (M_V)}{(F_O)\ (W_V)\ (B_m)} \qquad \text{EQ III-6C}$$

Where:

S_V = Allowable vertical conductor span

M_v = Maximum allowable moment of the crossarm in the vertical plane
N = Number of crossarms
W_v = Conductor weight per unit length
B_m = Summation of conductor moment arms

3. Determination of Maximum Allowable Moment of Crossarms

The allowable moment arm of the crossarm about the point of attachment to the pole can be determined by the following:

$$M_a = (F_b)(X) \qquad \text{EQ III-6D}$$

Where:
F_b = The designated bending stress
X = The section modulus of the arm

The section modulus for resisting longitudinal loads is:

$$X_h = \frac{(d-a)(b^2)}{6} \qquad \text{EQ III-6E}$$

The section modulus for resisting vertical loads is:

$$X_v = \frac{(d^3 - a^3)(b)}{6d} \qquad \text{EQ III-6F}$$

Where:
b = Horizontal dimension of the arm
d = Vertical dimension of the arm
a = Diameter of bolt hole

The dimensions b and d are nominal arm dimensions, less tolerance.

Examples of calculations of maximum allowable moments are included in REA Bulletin 62-1, Design Manual for High Voltage Transmission Lines. Maximum allowable bending moments for REA standard distribution crossarms are provided in Table III-1. These maximum values are based on designated fiber stress values given in Bulletin 62-1. The maximum allowable moments provided are subject to change if modifications are made to the arm such as enlarging the bolt hole. Appropriate NESC overload capacity factors are applied to the loads supported by the arms.

4. NESC Vertical Loading Requirements

NESC strength requirements for crossarms are covered under Rule 261 D. An overload capacity factor (F_o) of two is required for both Grades B and C construction when the crossarm is subjected to the final maximum design loading of the conductor.

At Grade B crossings where pin type construction is used, the NESC requires the use of double crossarms or supports of equivalent strength at each crossing structure, at ends of joint use or conflict line sections, at dead ends and at corners where the line angle exceeds 20°.

In areas subject to heavy icing of conductors, it may be advisable to increase the overload capacity factor for large and extra large conductor three-phase lines which supply many consumers.

5. Example Vertical Span Problem

For a type VC1-2 pole top assembly, determine the maximum vertical span, using 266.8 kcmil (26/7) (Partridge) ACSR conductor, Grade C construction, heavy loading district. The tabulation of data together with source is listed on the following page.

TABLE III-1

MAXIMUM ALLOWABLE BENDING MOMENTS OF REA CROSSARMS

(Maximum permissible crossarm loading, including overload capacity factors)

Nominal Dimensions[1]		Allowable Moments[2]	
Vertical	Horizontal	M_v	M_h
CUSTOMARY ARMS			
4 5/8 in	3 5/8 in	9840 N•m [7260 lb•ft]	6500 N•m [4800 lb•ft]

[1]Values used in computation were as follows:
Arm dimensions: nominal less following tolerances: 3 mm [1/8 in]
Bolt holes: 17.5 mm [11/16 in]
Designated fiber stress: 51 000 Pa [7400 lb/in²]

[2]As of the date of this publication, ANSI standard dimensions for metric crossarms had not been established. Allowable moments for metric arms should be calculated if dimensions are appreciably different than the REA standard customary arms.

N = 1, from REA Drawing VC1-2 shown by Figure III-1

M_V = 10 100 N•m [7380 lb•ft], from Table III-1

F_O = 2, NESC o.c.f. Grade C for crossarm

W_V = 15.726 N/m (1.0776 lb/ft), from Appendices A and B

B_m = 3'-4" or 1.015 m (3.33 ft), from REA Drawing VC1-2

$$S_V = \frac{(N)\ (M_V)}{(F_O)\ (W_V)\ (B_m)} \qquad \text{EQ III-6G}$$

- **Metric Solution**

$$S_V = \frac{(1)\ (9840)}{(2)\ (15.726)\ (1.015)} = 302 \text{ m}$$

- **Customary Solution**

$$S_V = \frac{(1)\ (7260)}{(2)\ (1.0776)\ (3.33)} = 1011 \text{ ft.}$$

6. Horizontal Loading Design

Horizontal loading of the crossarm results from conductor longitudinal unbalances, the most severe unbalances occurring at single dead-ends. The NESC does not specify an overload capacity factor for loading of crossarms. However, to provide an overload capacity consistent with other line components, REA specifications limit the unbalanced loaded tension on 2440 mm [8 ft] crossarms to 4450 N [1000 lb] for two crossarms and 6675 N [1500 lb] for three crossarms. The loading limitations are shown on the construction drawings for the dead-end pole top assemblies.

These limits permit only the smaller, low-strength conductor to be dead-ended on standard crossarms. This should not be a matter of concern at a three-phase line dead end, since this construction usually will be associated with a small conductor branch circuit serving a three-phase transformer bank at the end of the line.

7. Alternate Methods of Dead-ending Conductors

Several alternatives are available for large conductor line angles that require dead-ending of the conductor.

- **Vertical Construction**
  This is the recommended method since vertical structures are economical and relatively convenient to maintain or work while the conductors are energized.

- **Buckarm Construction with Bridle Guys**
  Buckarm or square corner construction using standard crossarms and bridle guys to support the unbalanced tension is expensive and difficult to maintain while the conductors are energized. The use of this type of construction should be limited.

- **Buckarm Construction without Bridle Guys**
  The comments above for buckarm construction with bridle guys also apply to this construction.

  Where there is no alternative to using this type of construction, it is recommended that as a minimum, the crossarm assembly be designed using the same overload capacity factors as required for the other components of the dead-end structure. Longitudinal overload capacities for a dead-end structure are as follows:

  NESC Grade B at dead-ends: F_O = 2.0
  NESC Grade C at dead-ends: F_O = 1.33

  For extra large conductors, it is recommended that Grade B overload capacity factors be used for designing unguyed dead-end crossarm assemblies.

C. STRENGTH OF CROSSARM BRACING

The NESC requires all crossarms to be securely supported by bracing, if necessary, to support all loads including the weight of linemen. The NESC also requires that any crossarm, except the uppermost arm, be capable of supporting a vertical load of 1000 N (225 lb) at the outermost extremity in addition to the weight of the conductors.

REA standard drawings for pole top assemblies utilize braces which will normally satisfy the NESC requirements. The braces are as follows:

- **Small Conductor Pole Top Assemblies**
  For small conductors, two 710 mm [28 in] long braces are used.

- **Large Conductor Pole Top Assemblies**
  For large conductors, braces having a 1525 mm [60 in] span and a breaking strength greater than 20 000 N [4500 lb] are used.

Where both outer phase conductors are uniformly loaded, the braces are placed in compression and add significantly to the strength of the crossarm. Where uniform loading applies at the outer pin positions, tests show the crossarms usually fail at the pole bolt hole in the following ranges:

700 mm [28 in] braces:
17 800-25 700 N [4000-6000 lb]
1500 mm [60 in] span braces:
35 600-44 500 N [8000-10 000 lb]

When the outer phase conductors are not uniformly loaded, one brace is placed in compression while the other brace is placed in tension. This condition frequently occurs when ice unloads from the line. In this case, the brace assembly usually fails rather than the crossarm. With loading applied at one of the outer pin positions, tests show that the braces will fail with a vertical load in the range of:

700 mm [28 in] braces:
3600-4900 N [800-1100 lb]
1500 mm [60 in] span braces:
8900-13 400 N [2000-3000 lb]

D. STRENGTH OF SUSPENSION INSULATOR ASSEMBLIES

Suspension insulator assemblies are used for supporting conductors on large angle running corners, e.g., type C3 pole top assemblies and for dead-ending conductors, e.g., types C4, C5, C7, and C8 pole top assemblies. The insulator assemblies of these pole top assemblies are loaded in tension.

The allowable strength of the assembly is generally dependent on the ANSI M&E (mechanical and electrical) rating of the suspension insulators. The NESC limits the tension loading on such insulators to 50 percent of the M&E rating. The other hardware materials used in the assembly, as shown on the REA construction drawings, are generally strong enough that the insulator is the critical material item in the assembly.

The allowable strength of the insulator then limits the span length and/or the permissible angle on running corner assemblies and limits the maximum loaded conductor design tensions at dead-end assemblies.

Following are the maximum allowable loads for insulators included in the REA construction drawings:

- **ANSI Class 52-1 Clevis Type Insulator**
  This is the 6 3/4-inch suspension insulator used on all 12.5/7.2 kV construction drawings. The M&E rating is 10 000 pounds, therefore the NESC allowable tension loading is 22 200 N [5000 lb].

  For 12.5 kV three-phase lines using extra large conductors, it may be desirable to substitute ANSI Class 52-4 insulator assemblies.
- **ANSI Class 52-4 Clevis Type Insulator**
  This is the 9-inch, 9 1/2-inch, or 10-inch suspension insulator used as an alternate on 24.9/14.4 kV construction and as the basic insulator for 34.5/19.9 kV construction. The M&E rating is 15 000 pounds, therefore the NESC allowable tension loading is 33 300 N [7500 lb].

  This insulator will accommodate the great majority of conductor design tensions found on distribution lines. For very large conductors and other unusual conditions, an ANSI Class 52-6 can be substituted.
- **ANSI Class 52-6 Clevis Type Insulator**
  This is the 10-inch suspension insulator used as an alternate for extra large conductor dead ends on the transmission lines. The M&E rating is 25 000 pounds, therefore, the NESC allowable tension loading is 55 500 N [12 500 lb]. Where this insulator is used, it may be necessary to substitute certain items of other hardware in the insulator assembly to coordinate with the strength of the insulator.

E. STRENGTH OF PIN AND POST TYPE INSULATOR ASSEMBLIES

Pin type and post type insulator assemblies are used for supporting conductors on small angle and medium angle pole top assemblies, e.g., C1 and C2 pole top assemblies.

The capability for these assemblies to withstand the transverse loads imposed by the conductors is usually determined by the most critical of the following:

- Capability of the pole and crossarm to resist splitting due to the torque action of the insulator pin;
- Capability of the pole top and crossarm insulator pins to withstand bending or compression of wood members under flanges;
- Capability of a post type insulator to withstand rated cantilever loading with the NESC safety factor of 2.5 (40 percent of rated strength).

The various insulator assemblies used in REA standard drawings are given nominal ratings based on the most critical of the above. The transverse loading capability of the entire pole top assembly is usually dependent on the most critical nominal rating of the various components used in the pole top assembly.

Nominal ratings of the various insulator assemblies are listed in Table III-2.

TABLE III-2

STRENGTH OF PIN AND POST TYPE INSULATOR ASSEMBLIES

Description of Insulator Assembly	Nominal Rating
Single pole top pin as used in A1 assembly	2224 N (500 lb)
Double pole top pin without split bolt as used in A1-1 assembly	2224 N (500 lb)
Double pole top pin with split bolt as used in A2 assembly	4448 N (1000 lb)
Single pole top post insulator and bracket as used in ZC1 assembly	3336 N (750 lb)
Double pole top post insulator and bracket with split bolt as used in ZC2 assembly	6672 N (1500 lb)
Single crossarm pin as used in C1 assembly	2224 N (500 lb)
Single crossarm pin with 57 mm (2 1/4 in) square washer under shoulder of pin as in C2-1 assembly	3336 N (750 lb)
Single saddle pin as used in C1-2 assembly	4448 N (1000 lb)
Double saddle pin as used in C2-2 assembly	8896 N (2000 lb)
Single post insulator as used in ZC1 assembly	3336 N (750 lb)
Double post insulator as used in ZC2 assembly	6672 N (1500 lb)

F. MAXIMUM LINE ANGLES ON PIN AND POST INSULATOR ASSEMBLIES

The NESC does not provide overload capacity factors for the transverse loading of pin and post type insulator assemblies. It is left to the designer to exercise good engineering judgment in the selection of overload factors. The following method has been proven by experience to provide satisfactory results on systems of REA borrowers and is recommended for use on rural distribution systems.

The maximum permissible line angle for a given wind span is determined by the following equation:

$$\sin(\theta/2) = \frac{P - (F_W S_W W_W)}{2 F_t T} \qquad \text{EQ III-6H}$$

Where:

θ = Maximum permissible line angle

P = Nominal rating of insulator assembly from Table III-2

S_W = Wind span (1/2 of sum of adjacent spans)

W_W = Wind load per unit length of conductor for design loading condition

T = Conductor tension for design loading condition

F_W = Overload capacity factor for wind load

F_t = Overload capacity factor for tension load

The overload capacity factors selected are those given by NESC for guys in NESC Table 261-5 and are as follows:

F_W = 2 for Grade C (2.67 for Grade B)

F_t = 1.15 for Grade C (1.5 for Grade B)

Historic application of this equation was to assume a design tension of 50 or 60 percent of the ultimate strength of the conductor regardless of the actual design tension. This proved to be conservative for short ruling span designs but not for long ruling spans. With increasing use of larger distribution conductors, it is more practical to use realistic design tensions. The possible reduction in strength for short ruling spans is offset by a change in the 1977 NESC which increased the value of F_W by 12.4 percent and F_t by 15 percent.

- **Example Problem**

Find the maximum permissible line angle for a Type VC2-2 pole top assembly, with a 75 m wind span, 336.4 kcmil (26/7) ACSR conductor

with design tension at 50 percent of ultimate strength and NESC heavy loading. Find the conductor data in Appendix B and conversion factors in Appendix A.

P = 8896 N (2000 lb), (VC2-2 has 2 saddle pins per conductor)

S = 75 m (246 ft)

W_w = 8.431 N/m (0.5777 lb/ft), (horizontal component of loaded conductor)

T = 31 360 N (7050 lb), (Ultimate strength is 14 100 lb)

- **Metric Example**

$$\sin(\theta/2) = \frac{8896-(2 \times 75 \times 8.431)}{2 \times 1.15 \times 31\,360}$$

$$= 0.106$$

$$\theta = 12.1°$$

- **Customary Example**

$$\sin(\theta/2) = \frac{2000-(2 \times 246 \times 0.5777)}{2 \times 1.15 \times 7050}$$

$$= 0.106$$

$$\theta = 12.1°$$

By repeating the computation for a range of wind spans, a pin strength staking design guide table can be prepared. For any single table, use the design tension for the ruling span.

Note the above design tension requires the use of an ANSI Class 52-4 dead-end insulator; if an ANSI Class 52-1 insulator is to be used, the design tension is reduced to 22 200 N [5000 lb]. The permissible line angle would then increase to 17.2°.

PART IV
SELECTION OF CRITERIA FOR LINE DESIGN

INTRODUCTION

The selection of the design criteria has been identified as a step in the process of designing the overhead distribution line. This part will define the effort, purpose, or output of this step of the design process.

The selection of design criteria consists of the review of the factors which might influence the engineering design of the line, the making of decisions concerning these factors, and the issuing of a statement in regard to the decisions which will provide the necessary direction to those preparing the detailed design for the line. The statement may be a single sentence or a number of pages, so long as it accomplishes the purpose.

Like all phases or steps in the design process, the magnitude of the effort required will depend on the nature of the specific project. The design criteria statement may simply indicate the utility's standard design for the particular conductor size which will be used. On the other hand, for a major new line with a new voltage class, new conductor size, and a new basic pole top assembly, the determination of the criteria may be based on economic analysis and engineering design studies of alternate types of construction. In the latter case, a well defined outline of the design requirements should be provided.

This part of this design manual reviews some of the factors which should be considered in the selection of the design criteria, and discusses some of the items which should be included in a design outline for a complete new line design.

This part also includes a discussion concerning the fundamentals of conductor design which might assist the design engineer in the selection of conductor and basic conductor design criteria.

CHAPTER IV-1
EVALUATION OF EXISTING DESIGN CRITERIA AND GUIDES

A. USE OF EXISTING DESIGN CRITERIA AND STAKING DESIGN GUIDES

Most rural distribution utilities have existing design criteria and staking design guides for the conductor sizes most commonly used on the system. A complete new guide is most often required when a new conductor size or type is introduced into the system. Usually an existing design guide can be modified to accommodate unusual local conditions on a specific line.

It is necessary, however, to periodically review the existing design criteria and staking guides to assure that they do conform to present requirements of the NESC and local administrative authorities. Depending on the nature of any code changes, it may be possible to update the design data by minor modification of the data, or it may be necessary to completely replace the data.

Staking design data used prior to the 1977 NESC is suspect and probably needs replacement. Much of this staking design data was prepared in the early years of the REA rural electrification program and essentially became industry standards. Beginning about 1960, dimensional changes on some REA standard drawings, dimensional and strength changes to some line material standards, improved conductor design data due to computerization, code variations adopted by local administrative authorities increasingly invalidated the data used prior to the 1977 NESC. The major changes in clearance and strength requirements of the 1977 NESC essentially completed the invalidation. In most cases, updating this old data requires more effort than the complete replacement of the data.

Appendix C of this design manual provides replacement guides for some of the historic conductor staking design guides.

B. OPERATING EXPERIENCE OF EXISTING LINES

The NESC, as well as this design manual, indicates local conditions should be considered in the design of the lines. There is no better indicator of the validity of existing line design for

local conditions than the actual operating experience of lines based on the design. Of particular value, is the operating experience under adverse weather conditions. When there are repeated experiences with the same problem, the design criteria and staking data should be examined. If it is concluded the design is inadequate for the local conditions, the criteria and data should be modified before it is used for more lines. It may be worthwhile for the design engineer and operations superintendent to periodically make a field inspection to locate such problems.

System experience factors should be utilized by the design engineer, not only for upgrading of a particular design, but also in the development of new designs.

CHAPTER IV-2
DEVELOPMENT OF DESIGN CRITERIA FOR NEW LINE DESIGN

A. DESIGN CRITERIA FOR A COMPLETE NEW LINE DESIGN

This chapter discusses the considerations and procedures for the selection of the design criteria for a complete new line design.

The completed design criteria is essentially a design outline or a statement of the parameters which are to be used in the preparation of the detailed design data to be included in the staking design guide.

The purpose of the design criteria is to give organized direction to preparation of the detailed design. The design criteria establishes the kind of line to be built and the general rules and guides to be followed in the detailed design of the line.

Where alternative types of line construction are under consideration, the design criteria selection process will probably include economic comparisons of construction costs. For such comparisons, some design analysis may be required to determine the average number of construction units per kilometer or mile of line for each alternative. Some engineering analyses or judgments should be made for the alternatives concerning impact on design, construction, operation, maintenance and reliability.

After the type of construction has been selected, there are other design alternatives to be considered concerning pole heights and class, conductor sags and tensions, and similar factors which can affect cost and reliability.

One approach to this analysis is to prepare alternate designs for several spans of a typical line section based on assumed average conditions anticipated in the actual staking and construction of the line. The most practical design is selected and used to establish the basic: conductor design, design ruling span, design average span, pole height and class, tangent pole top assembly, clearances, and design and construction tolerances. This basic design, together with the design parameters used in the preparation of the basic design, establishes the basic design criteria.

The same design concepts and calculation methods are used for preparing these preliminary basic designs and are later used to prepare the detailed design data to be included in the staking design guides. In the first case, the concepts are used to select and define a basis for the design, in the second case, the concepts are used to prepare additional data to facilitate the field design where actual conditions differ from those assumed for the basic design.

This part of this design manual provides assistance in the selection of conductor design. The design concepts and calculation methods for other components of the line are covered in other parts.

B. DETERMINATION OF BASIC DESIGN CRITERIA

Some of the parameters which are used in the determination of the basic design criteria are imposed on the utility while others are selected by the utility.

Those conditions which are imposed on the utility include:

- Conformance with the requirements of the NESC;
- Conformance with the rules and laws of local administrative authorities;

- Local geography, topography, and weather conditions;
- Strength limitations of available materials;
- Changing economic conditions which might have impact on line design.

Conditions which are the option of the utility can be subdivided into two categories, those which have been adopted as standard practice and those which are at the option of the line designer. Standard practice conditions may be set by the chief engineer, utility management, or the board of directors. These conditions can be changed, but only by those with the authority to make such changes. The options left to the designer are those which are not established utility standards. Utility standards might include:

- Standard basic size and types of materials, selected to minimize warehousing costs;
- Standard construction and maintenance safety practices which may limit design clearances or material strengths;
- Standard design loading conditions to compensate for unusual local weather conditions;
- Standard uniform design and construction clearance tolerances;
- Approved long range and construction work plans;
- Specific management directives concerning design parameters for a given line.

The design engineer proceeds to determine the basic line design criteria subject to the preceding restrictions. Because of the options available in sizes of poles and other materials and assemblies, several options will be available for basic spans and other basic elements. The most practical of these alternatives should be compared to determine the one with the lowest construction cost. In making such comparisons, due consideration must be given to how the basic design will adapt to actual field conditions. For example, a basic line design for 200-meter [600-foot] average spans may appear to have a lower cost than a line design for 100-meter [300-foot] average spans. However, if local conditions are such that the average span cannot be much longer than 100 meters, actual design based on the 100-meter span may, in fact, cost less than the one based on 200-meter spans.

The elements of the basic design criteria for the line design are:

- Conductor size and type;
- Basic conductor design tension limits;
- Basic pole height and class;
- Basic conductor support assembly;
- Basic design and construction tolerances;
- Basic design average span;
- Basic design ruling span;
- Basic guying design;
- Basic structure strength requirements.

C. CONDUCTOR SIZE AND TYPE

Conductor size should be determined from the long-range plan, construction work plan, or by the ampacity needs of the consumer. Conductor type may be selected for many different reasons such as strength requirements, economics, contamination problems, and preferences of the cooperative. Selection of conductor types is discussed in more detail in Chapter IV-10.

D. CONDUCTOR TENSION LIMITS

In addition to conductor limitations required by the NESC, other factors may limit conductors tension, such as aeolian vibration, guying, or unusual mechanical loading conditions, and should be considered. Conductor tension limits are discussed in detail in Chapter IV-7.

E. BASIC POLE HEIGHT AND CLASS

Clearances required by the current NESC will generally necessitate a minimum basic pole height of 11 meters [35 ft.]. In some cases, underbuild of the cooperative or some other utility may require additional base pole height. The selection of the basic pole class must be coordinated with and provide the strength for the selected basic span. Additional considerations concerning pole class are included under the discussion of the horizontal span later in this chapter.

F. CONDUCTOR SUPPORTS

The type and strength of the pole top assembly must be selected to coordinate with the conductors to be supported. The type of conductor support sets the vertical and horizontal spacing of the conductors and therefore the conductor support for the base pole must be con-

sidered an integral part of the basic structure when analyzing basic spans for the design criteria. The selection of primary conductor supports is discussed in detail in Part III.

G. DESIGN AND CONSTRUCTION TOLERANCES

The need for design and construction tolerances has been stressed throughout this design manual. Code limits are mandatory limits which should not be exceeded. Line design and construction cannot be controlled to the degree necessary to meet code limits exactly without exceeding these limits. It is therefore necessary to provide margins of safety sufficient to assure the code limits will not be exceeded.

The need for these tolerance limits is to a considerable extent dependent on local conditions and normal practices of the utility in staking and construction of the lines. The best guide is probably experience of the local utility. Clearance tolerances are usually "add on" length values. Strength tolerances are usually multipliers which are applied to the overload capacity factors.

It is virtually impossible to accurately predict the exact behavior of conductor sags. Therefore, design tolerances are needed for clearances such as ground clearances or blowout clearances since they are dependent on the conductor sag. It is also difficult to exactly control the conductor sagging, setting depth of poles, and measurement of ground elevation throughout the span. Therefore, tolerances are also needed to compensate for possible staking or construction errors.

Where local weather conditions are known to be more severe than designated for the applicable NESC loading district, it may be advisable to increase the magnitude of the overload capacity factors. It also may be desirable to arbitrarily increase the strength of lines which require very high reliability. This can be done by upgrading the line from Grade C to Grade B construction or by increasing the overload capacity factors to some value greater than the minimum required value.

It is recommended that design and construction tolerance values be adopted as utility standard practice and, as far as practical, be used uniformly throughout the system. Those which are associated with line components and clearances used in selection of the basic design criteria should be included as a part of the design criteria.

H. BASIC DESIGN AVERAGE SPAN

The basic line design is to a great extent determined by a selected basic design average span. The basic design average span is an estimated span selected by engineering judgment with due consideration given to the following limitations:

- Level ground span, a function of structure height;
- Horizontal span, a function of structure strength;
- Vertical span, a function of structure strength;
- Conductor separation, a function of structure configuration;
- Probable average span, a function of local conditions.

The most practical economical line design is achieved when these limitations are coordinated as well as possible.

1. Level Ground Span

The length of the level ground span is determined by the midspan clearance to ground of the conductor which controls the clearance. The span length can be increased if there is a depression at midspan and the permissible span decreases in length if there is a rise at midspan. On a line having no span limiting conditions other than ground clearance, it is probable there would be as many spans shorter than the level ground span as there would be spans longer than the level ground span. The level ground span thus represents a mean or average span length. Level ground is somewhat of a misnomer because the above is true as long as the midspan elevation falls on a straight line between the ground elevations at the poles.

The level ground span is a function of conductor sag, clearance to ground plus an appropriate design and construction tolerance, and the height of poles used for the supporting structures. The clearance used should be the prevalent clearance to ground for the system. For rural lines this will normally be the NESC clearance over "other lands" (NESC Clearance Category 4, NESC Table 232-1, or Table II-4 of this design manual).

The normal procedure for determining the basic level ground span is to calculate the level ground span for several different pole heights and to select the basic pole height which will ac-

commodate the majority of probable spans anticipated for the system.

2. Horizontal Span

The maximum horizontal span or wind span of a structure is determined by the capability of the structure to withstand the crosswind loading on the conductors and the structure. The components of the structure exposed and most affected by this loading are the pole and insulator pins. The following discussion relates to pole strength selection.

The horizontal span is determined for the basic pole height selected when determining the basic level ground span. The maximum horizontal span is calculated for several pole classes of the base height. The basic class selected for the base pole should be the one that will accommodate the majority of probable spans on the system.

If the range of the horizontal span for a specific pole class is defined as being between the upper limit of the next lower class and the upper limit of the specific class, the average horizontal span of the pole class can be defined as the midspan of the range.

The average horizontal span of the base pole should approximate the probable average span of the system. The average horizontal span and the basic level ground span should be coordinated as close as possible, but are not directly related. The most economic design is achieved when the level ground span, the average horizontal span, and the probable average span of the system are equal, however, the probability of this occurring is small.

In most cases the probable average span of the system will be somewhat less than the level ground span, therefore, the average horizontal span may also be less.

3. Other Limiting Spans

The vertical span, which is a function of the weight supported by the components of the structure, conductor separation span, and the horizontal span based on pin strength are all functions of the strengths and dimensions of the conductor supporting assemblies. All of the factors can be resolved in terms of a maximum span limitation.

The REA standard primary pole top assemblies have been designed to accommodate the majority of basic level ground and horizontal spans encountered on rural lines. Some strength options are available and the assembly should be selected so it is not more limiting than the basic horizontal span. For large conductors particular attention should be given to vertical strengths of crossarms and other conductor supports, and to pin strength. Maximum spans based on separation should be examined but will not usually be limiting for basic tangent structures. In areas subject to icing and galloping of conductors, it is advisable to consider the effect of conductor separation and configuration on span lengths. In such areas the maximum span based on galloping conductors should be calculated for the basic pole top assembly and identified as a span limit. This is usually more of a problem on special narrow profile pole top assemblies than on the standard type C1 assemblies. The method for determining such span limitations is well covered in the current edition of REA Bulletin 62-1, Design Manual for High Voltage Transmission Lines.

4. Probable Average Span

The basic average span used in the basic line design should approximate the probable average span of the system. However, the actual average span cannot be defined until after the line is staked. It is therefore necessary to estimate the basic span.

The average span is, to a considerable extent, influenced by factors beyond the control of the engineer who establishes the design criteria or the staker who designs the line in the field. It is affected by geography, topography, and other factors which establish control points which dictate or limit locations of structures.

In flat, sparsely populated areas with few control points, the level ground essentially sets the average span and basic pole class.

In areas with rough terrain, irregular roads and/or a high density of consumers, the level ground will not control the span length and the average span is estimated, as well as practical, to suit these local conditions.

The designer examines the possible level ground spans, the possible average horizontal spans and with knowledge of the local conditions, selects a basic design average span which in the designer's judgment will approximate the anticipated average span which will result from the line design.

I. BASIC DESIGN RULING SPAN

The basic design ruling span, like the basic

design average span, is an estimated span. The equations for estimating the ruling span of a line section are given in Chapter IV-5.

The estimated ruling span is a function of the basic design average span and some estimated maximum span. The value used for the maximum span should represent the average of the maximum spans in each of the conductor stringing sections.

Local conditions may be such that the actual average span of each staked section of line may vary considerably. Under such conditions, it is also probable the theoretical ruling spans will vary. In this case, it may be necessary to develop alternate design ruling spans for use where the theoretical ruling span will fall outside the acceptable range of the basic design ruling span. This will not cause need for complete alternate design packages, provided each guide in the staking design guide package is based on the most restrictive of the several design ruling spans which may be encountered.

J. BASIC GUYING DESIGN

Basic guying design utilizes the most efficient (one-to-one) guy slope. Guy designs are developed for dead-ends and the largest practical bisector guy angles. The basic guying is coordinated with the other basic design criteria. In some cases the guying design will influence other basic design parameters. For example, a slight reduction in conductor design tension may result in considerable savings in guy and anchor design. This will occur if the change reduces the number or size of the guy strands and anchor assemblies required at dead ends.

K. BASIC STRENGTH REQUIREMENTS

The basic strength requirements for the supporting structures are based on an intricate interplay between NESC strength requirements, allowable strength of structure components and conductor design tensions. The basic strength requirements are discussed in detail in Chapter IV-11.

L. PREPARATION OF STAKING DESIGN GUIDE

When the basic design criteria for a line design has been established, the preparation of the staking design guide data can proceed. The methods for preparing this data are discussed in Part V of this design manual.

CHAPTER IV-3
CONDUCTOR AS A BASIS FOR LINE DESIGN

A. INTRODUCTION TO CONDUCTOR DESIGN

Of all the components which go into the design and construction of the overhead distribution line, none is more important than the conductors, and none will have more impact on the design criteria and detailed design of the line.

The selected conductor and associated conductor designs are, next to the NESC, the most important factors in establishing the basis for the total line design. In fact, the great majority of the rules of the NESC deal with the clearances from the conductor and the strength of the supports required to protect the public from the possible dangers of contact with energized conductors.

Of all the variables the designer must deal with, the behavior and movement of the suspended conductor is the most unpredictable.

The most complicated computations involved in the design of an overhead line are the conductor design computations. Some are so complicated most utility design engineers will have to seek assistance from the engineering staff of the conductor manufacturers or qualified consultants. Those conductor computations which appear to be simple, are so because approximate equations are used rather than exact equations.

The purpose of the following chapters is to assist the distribution design engineer in understanding conductor design computations and also to help establish better means of communicating with conductor specialists when their assistance is needed.

CHAPTER IV-4
CONDUCTOR SAG AND TENSION CALCULATIONS

A. MATHEMATICS OF CONDUCTOR DESIGN

Those who are beginning the study of conductor design are sometimes confused by the variety of equations and methods in the literature concerning conductor sag and tension relationships. Equations of varying degrees of complexity can be found, seemingly for the same purpose. Some of the relationships do not appear to follow the fundamental rules of physics and mathematics.

The true mathematics of the conductor sag curve are extremely complicated; therefore, some simplifications and approximations are used even when performing the calculations with the aid of sophisticated computer programs. Since the methods used are not exact, some degree of error exists. The complexity of the particular form of the equation used is determined by the degree of accuracy required of the results.

The purpose of this chapter is to identify the form of the equations used by distribution design engineers and to discuss the application.

B. CATENARY AND PARABOLIC SAG EQUATIONS

The curve shape assumed by a completely flexible cable when suspended between two rigid supports is defined as a catenary. A conductor cable, although not completely flexible, very nearly assumes this same shape. The equations for the catenary are quite difficult to manipulate. Therefore, various mathematical simplifications have been used to approximate the catenary. The equation for the catenary is found expressed in two forms which are mathematically equal: For conductor design, the equation for sag is as follows:

- **Exponential Form:**

$$D = \left(\frac{T_h}{2W}\right)(e^u + e^{-u}) \qquad \text{EQ IV-4A}$$

- **Hyperbolic Form:**

$$D = \left(\frac{T_h}{2W}\right)\cosh u \qquad \text{EQ IV-4B}$$

Where:

$$u = \frac{SW}{2T_h}$$

D = Conductor sag at midspan
T_h = Horizontal component of conductor tension
S = Horizontal length of the conductor span
W = Unit vertical force (weight) of the conductor (including ice or wind loads)
e = Base number of the system of natural logarithms
cosh = hyperbolic cosine

The catenary equation can be approximated to the degree of accuracy desired by use of MacLaurins infinite series for hyperbolic functions. In this form, each added term in the series increases the accuracy. The series is given below with three terms included.

$$D = \left(\frac{WS^2}{8T_h}\right) + \left(\frac{W}{6T_h}\right)\left(\frac{WS^2}{8T_h}\right)^2 + \left(\frac{4}{10}\right)\left(\frac{W}{6T_h}\right)^2\left(\frac{WS^2}{8T_h}\right)^3$$

EQ IV-4C

Three terms of this equation will usually be sufficient for exacting sag problems, two terms will generally provide the necessary accuracy for long span transmission lines, and a single term will satisfy the requirements for the majority of distribution and lower voltage transmission lines. When all but the first term of the equation are dropped, the equation is found to be identical to the equation for a parabolic curve.

- **Parabolic Sag Equation:**

$$D = \frac{WS^2}{8T_h} \qquad \text{EQ IV-4D}$$

The basic difference between the catenary and the parabola is the catenary correctly assumes the weight of the conductor in the span to be distributed along the conductor sag curve. The parabola assumes the weight to be distributed evenly along a straight line between the conductor supports. For relatively short spans with small sags, the difference between the two methods is small or negligible.

The parabolic equation is used for the great majority of the manual sag and tension calculations for distribution lines. Catenary equations of several terms are used in some computer programs where high accuracy is desired. About the only application a distribution design engineer might have for a two-term catenary

would be to check the sag error of a parabolic calculation for a long crossing span. The catenary equation will show larger sag values than the parabolic equation.

Parabolic equations will be used in this design manual unless otherwise indicated.

C. DEAD-END SPAN SAG AND TENSION EQUATIONS

Most conductor sag and tension calculations are based on the mathematical theory of a simple dead-end span of conductor supported at equal elevations. The supports are assumed to be rigid.

For most of the computations made by distribution engineers, it is assumed the conductor does not change in length with change in temperature or stress. With these assumptions, the calculations can be made with simple equations of the parabolic curve.

The variables of the simple parabolic span together with designated symbols are described as follows:

- **Conductor Span:**

  S = Conductor span length between supports, unless indicated otherwise by subscript, should be assumed to mean the horizontal distance between supports
  S_h = Conductor horizontal span length
  S_s = Slope span length, distance along a straight line between conductor supports
  S_r = Ruling span
  S_e = Estimated ruling span

- **Conductor Sag:**

  D = Conductor sag, unless otherwise indicated, assume it is the vertical midspan sag
  D_a = Apparent sag, the perpendicular distance from a straight line between supports to the conductor at midspan
  D_r = Ruling span sag

- **Conductor Length:**

  L = Conductor length along the parabolic sag curve

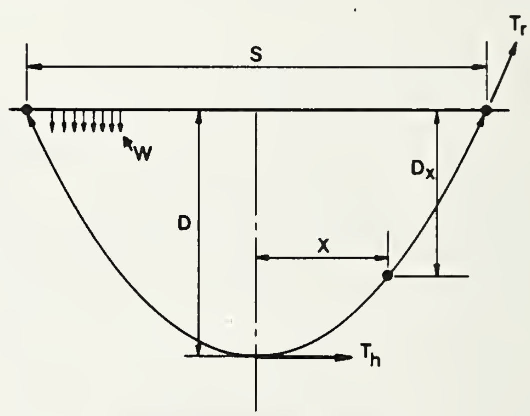
- **Conductor Tension:**

  T = Total conductor tension at any specified point in the span
  T_h = Horizontal or longitudinal component of tension at any point in the span, for a parabolic span it is assumed to be constant throughout the span. At the low point of sag the vertical component of sag is zero, therefore the horizontal tension is the total tension at that point
  T_v = Vertical component of tension at designated point in the span, unless otherwise indicated, assume it is the vertical component of tension at the support
  T_r = Resultant conductor tension, unless otherwise indicated, assume it is the resultant tension at the support
  T_a = Average tension of the conductor span

- **Conductor Vertical Force (Weight)**

  W = Unit vertical force (weight) of conductor, usually newtons per meter or pounds per foot. Includes force of conductor plus any ice or other load.

Figure IV-1 illustrates the parabolic conductor sag curve and locates some of the principal variables.



PARABOLIC SAG CURVE

FIGURE IV-1

- **Sag equations:**

The fundamental sag equation for the parabolic sag curve of a conductor span is:

$$D = \frac{WS^2}{8T_h} \qquad \text{EQ IV-4D}$$

Usually W and S are known quantities. A value is assumed or determined for T_h or D and the equation solved for the unknown variable. If T_h

is decreased, D must increase, and vice versa. If T_h is held constant and the span varied, D will increase or decrease as a function of the square of the span length. This provides the basis for another frequently used sag equation. If S is assumed to be a base span or ruling S_r with the sag D_r, the sag can be determined for any other span with the same values of W and T_h.

$$D = D_r \left(\frac{S}{S_r}\right)^2 \qquad \text{EQ IV-4E}$$

The sag of the conductor at the distance (x) from the midspan or distance (z) from the support is found as follows:

$$Dx = D\left[1- \left(\frac{2x}{S}\right)^2\right] \qquad \text{EQ IV-4F}$$

$$Dz = D\left[1- \left(\frac{S-2z}{S}\right)^2\right] \qquad \text{EQ IV-4G}$$

Where:

x = Distance from midspan
z = Distance from support
Dx = Sag at point x
Dz = Sag at point z

- **Tension Equations:**

$$T_h = \frac{WS^2}{8D} \qquad \text{EQ IV-4H}$$

$$T_v = \frac{SW}{2} \qquad \text{EQ IV-4I}$$

$$T_r = Th+WD \qquad \text{EQ IV-4J}$$

The derivation of T_r is not obvious and is given below:

$$T_r=\left(Th^2+Tv^2\right)^{1/2} = Th\left(1+\frac{Tv^2}{Th^2}\right)^{1/2}$$

One of the conventional approximation formulas is used. In the expression $(1+a)^m$, if a is much smaller than one, then $(1+a)^m=(1+ma)$, therefore:

$$T_r=T_h+\frac{T_v^2}{2T_h} = T_h+\frac{W^2S^2}{8T_h} = T_h+WD$$

The average tension of the span is the average of T_h and T_r.

$$T_a = \frac{T_h+T_r}{2}$$

$$T_a = T_h+\frac{WD}{2} \qquad \text{EQ IV-4K}$$

Neither T_h nor T_r are generally known and are calculated. The tensions provided with sag-tension data for a specific ruling span are usually values of T_a. Since T_a, D, and W are known, T_h can be calculated.

$$T_h = T_a - \frac{WD}{2} \qquad \text{EQ IV-4L}$$

- **Conductor Length Equation:**

The length of conductor equation is used infrequently, but is as follows:

$$L=S\left(1+\frac{WD}{3T_h}\right)=S\left(1+\frac{W^2S^2}{24T_h^2}\right) \qquad \text{EQ IV-4}$$

D. APPLICATION OF EQUATIONS TO ACTUAL DESIGN CONDITIONS

The simplified parabolic equations given in the previous section are relatively easy to use. However, in actual practice they are applied to design and construction conditions which do not always agree with conditions on which the equations are based. It is therefore necessary to examine the impact of violation of these assumed conditions. The assumed conditions of most concern are:

- The conductor length is constant or in a steady state condition.
- The conductor span is an isolated single span suspended between two rigid supports.
- The conductor span supports are at equal elevations and the span is said to be a level span.

Conductor materials expand and contract with changes in both temperature and stress (tension). The change of length of conductor under tension has both elastic and inelastic stretch characteristics. Therefore, once the conductor is installed and sagged under certain conditions it will never return to exactly the same conditions. However, by applying equations dealing with the characteristics of the conductor behavior, it is possible to predict the future status of conductor sags and tensions for specified conditions of conductor temperature and loading. These computations are complex and are discussed in Chapter IV-6.

In actual construction practice, the conductor is not installed and sagged as a single dead-end span. The conductor for a section of line consisting of a series of unequal spans is installed and sagged in one operation. At the structures between the dead-ends of the stringing section, the conductors are supported on the free wheeling rollers of travelers (stringing sheaves or

blocks) which permit the conductor to move freely between spans. The behavior of the sag and tension during sagging is therefore a function of the length of conductor in the entire stringing section being sagged rather than a function of the single span where the sagging is done. The behavior of the conductor under these conditions is determined by the "Ruling Span Theory" which is discussed in the next section.

Once the conductor is sagged and secured to the supporting insulators, the conductor no longer can move freely between spans. The spans, in a sense, become dead-end spans. The supporting structures are not absolutely rigid and will flex to a degree when the horizontal tensions between spans are unequal. However, this difference in tension will be minimized if the sagging of the section was done in conformance with the ruling span theory. In practice this flexure is ignored and the prediction for future behavior of the spans are based on calculation procedures used for dead-end spans.

The elevations of supporting structures in the stringing section will usually not be exactly at equal elevations. However, for the great majority of spans the difference in elevation will be small compared to the span length. Therefore, for distribution lines, it is normal practice to ignore this difference in elevation when designing the line. There will be a few isolated cases where this practice will cause measurable differences between predicted and actual sags. These differences can be accommodated by increasing design and construction tolerance in terrain where large differences in support elevations occur. The differences can also be minimized by judicious choice of dead-ends for stringing sections. The behavior of the conductor under these conditions is not usually considered in the selection of design criteria or in preparing staking design guides. A discussion of these unusual conditions is discussed in Part VII, Line Construction and Inspection.

E. THE RULING SPAN THEORY

As indicated in the preceding section, during the period of stringing and sagging the conductor, the conductors are placed on travelers at the supports and are dead-ended at the ends of the stringing and sagging section of the line. While the conductor is on travelers and free to move between spans, the behavior of the conductor tension and length in any span is a function of the combined average tension of all spans and the total conductor length of the dead-ended stringing section.

When all the spans are of equal length and the supports of equal elevation, the behavior of the conductor in all spans will be identical and can be determined by the equations for the dead-end span. When the spans are of unequal length and the supports are of varying elevations, the mathematics become too complicated to be determined by most computers. Therefore, it is necessary to simplify the problem to one which can be calculated. What is needed is a simple method to determine a theoretical span length for which the sag and tension characteristics can be applied to determine the sag and tension behavior of all spans during the sagging operation. By making certain reasonable assumptions concerning the behavior of the conductor in a series of spans supported on travelers, the mathematics can be simplified to a manageable equation. The assumptions and the equation for the "Ruling Span Theory" which is based on these assumptions follows.

The first assumption is that since the span lengths are large compared to the difference in elevation of supports, any error will be negligible if it is assumed the supports are at equal elevations.

The second assumption is that the variation in span lengths will not be great enough to cause a measurable difference in the horizontal tension between any two adjacent spans. Thus, it is assumed the horizontal tension is constant throughout the stringing section.

The third assumption is that if the uneven spans could be replaced by a series of equal spans of such length, the total length of conductor and the horizontal tension of the section would be unchanged, then the sag and tension characteristics of a dead-end span, of that same length could be used to predict the sag behavior in any of the spans in the section.

The derivation of the equivalent dead-end span, based on the above assumptions, is very seldom seen in distribution conductor design literature and is given here.

This derived equation for the span length which rules the behavior of the spans of the stringing section is called the theoretical ruling span equation.

The length of conductor in a parabolic span is:

$$L = S + \frac{W^2S^3}{24T_h^2}$$

Therefore, the summation of the lengths of all the spans in a section of unequal spans is:

$$\Sigma L = \Sigma S + \frac{W^2\Sigma S^3}{24T_h^2}$$

If the length of conductor in the section (ΣL), the unit force (W), and the horizontal tension (T_h) are held constant and the section replaced with (N_r) spans of equal length (S_r), and (N_r) is not required to be a whole number, then:

$$N_rS_r = \Sigma S$$
$$N_rL_r = \Sigma L$$

Therefore:

$$N_rS_r + \left(\frac{W^2S_r^3}{24T_h^2}\right) = \Sigma S + \frac{W^2\Sigma S^3}{24T_h^2}$$

$$\frac{N_rS_r}{\Sigma S}\left(1 + \frac{W^2S_r^2}{24T_h^2}\right) = \frac{\Sigma S}{\Sigma S} + \frac{W^2\Sigma S^3}{24T_h\Sigma S}$$

And since:

$$N_rS_r = \Sigma S$$

$$1 + \frac{W^2S_r^2}{24T_h^2} = 1 + \frac{W^2\Sigma S^3}{24T_h^2\Sigma S}$$

Which reduces to:

$$S_r = \sqrt{\frac{\Sigma S^3}{\Sigma S}}$$

Which is the equation for the theoretical ruling span and is usually presented as follows:

$$S_r = \sqrt{\frac{S_1^3+S_2^3+S_3^3+\ldots S_n^3}{S_1+S_2+S_3+\ldots S_n}} \qquad \text{EQ IV-4N}$$

Where S_1, S_2, S_3, ... S_n are equal to the 1st, 2nd, 3rd, ... nth span lengths.

This equation is the derived ruling span equation based on the above assumptions. Because of the assumptions, the method is not exact; however, this is the method commonly used in design of most overhead distribution lines. Generally the accuracy is sufficient for most line design. Conditions where the inaccuracy may become a problem during line construction are discussed in Part VII of this design manual.

Since the horizontal tension and the unit conductor weight are assumed constant throughout the stringing section, the sag of any span in the section can be determined by Equation IV-4E.

$$D = D_r\left(\frac{S}{S_r}\right)^2$$

CHAPTER IV-5
RULING SPAN

A. RULING SPAN

The term "ruling span" is one of the most frequently used terms in the design, staking, and construction of overhead lines, and at the same time one of the most misunderstood and misused terms. In distribution design the term is most often used in connection with selection of conductor design and during staking.

Part of this confusion lies in that the term "ruling span" is loosely used to denote several different meanings which will be discussed. Properly, it should be preceded by a descriptive adjective to identify the specific meaning.

B. THEORETICAL RULING SPAN

The theoretical ruling span formula presented in the preceding chapter is the ruling span in its true sense. By various writers, it has been called: ruling span, theoretical ruling span, actual ruling span, true ruling span, and equivalent span.

It is an equivalent span length based on the total length and average tension of the conductor in a series of spans which is being pulled up and sagged in one operation. It is therefore, a function of all of the spans included in the stringing section.

It is a theoretical span whose sag and tension characteristics, when applied to the whole section, will result in the minimum difference in tension between the individual spans once they are tied off or clipped in and thereby become individual dead-end spans. When the individual spans in the section are of different lengths, once dead-ended (tied in), every change in temperature, elongation due to creep, and every change in loading will cause differences in tension between spans. This, in turn, causes flexing or bending of poles and arms in order to compensate for these differences in tension.

This span "rules" the behavior of the sagged section of line. The sag characteristics of the rul-

ing span set the sag characteristics of every span in the section. If the sag used for sagging the section is based on sag-tension data for any other span length, the resulting sags and tensions will not be as predicted. The greater the difference between the true theoretical ruling span and the "used" design ruling span, the greater the error will be in predicted results.

C. DESIGN RULING SPAN

It is apparent the true ruling span of the line section cannot be determined until it is staked. At the same time, the line cannot be staked without design criteria. Therefore, one or more design ruling spans must be assumed, based on experience, and used for field design.

If the land is reasonably flat, a ruling span that approximates the level ground span may be desirable. If the base structure is known, the minimum ground clearance and the design tolerance may be subtracted from the attachment height of the lowest conductor above ground to determine the sag limited by ground clearance. This sag value can then be used to determine a ruling span length whose sag is approximately equal to the sag allowed by the basic structure height. For terrain that is rugged, a ruling span that is longer than the level ground span usually proves more effective.

After staking, the theoretical ruling span should be determined and compared with the design ruling span. The use of a design ruling span appreciably different than the theoretical ruling span of the section results in unpredictable sag and tensions. Sags may be low enough to cause clearance problems or tight enough to cause uplift problems. Higher than predicted tensions may cause aeolian vibration problems.

The staking design guide should indicate the upper and lower limits of the range of true ruling spans for which the design ruling span data can be used without introducing too much error in predicted results.

D. ESTIMATED RULING SPAN

Knowledge gained from the line reconnaissance may make it possible to estimate a ruling span. A traditional "rule-of-thumb" equation that may be helpful in the estimation of a ruling span is:

$$S_e = \text{Avg. Span} + 2/3(\text{Max. Span} - \text{Avg. Span}) \qquad \text{EQ IV-5A}$$

Use this rule for estimating the ruling span with caution! If this "rule-of-thumb" is used indiscriminately, answers significantly different from the true ruling span may result. A few spans or even one span much longer than the average span may cause the estimated ruling span to be much greater than the actual theoretical ruling span. This formula should be used for estimating ruling span only when the actual spans are not yet known. When the spans are known, the theoretical formula should be used.

The above equation is convenient to use in the field because it can be solved with simple arithmetic. When an engineering calculator is available the following equation will generally provide more accurate results:

$$S_e = \sqrt{[(N-1)(\Sigma S - S_m)^3 + S_m^3] \div \Sigma S} \qquad \text{EQ IV-5B}$$

Where:

S_e = Estimated ruling span
ΣS = Estimated total length of all spans in stringing section
N = Estimated number of spans in stringing section.
S_m = Length of the estimated longest span in stringing section.

Another form of the above equation is as follows:

$$S_e = \sqrt{(N_e S_a^3 + S_m^3) \div (N_e S_a + S_m)} \qquad \text{EQ IV-5C}$$

Where:

N_e = Estimated number of spans in stringing section, exclusive of the longest span.
S_a = Estimated average span of stringing section, exclusive of the longest span.

E. CONTROLLING THE RULING SPAN

It has been indicated that design data based on a selected design ruling span is valid for a limited range of actual theoretical ruling spans. When the actual ruling span of a stringing section falls outside the limits of the basic design ruling span, data based on an alternate design ruling span should be used. For many reasons it is undesirable to change the design ruling span once the line is staked, therefore, an important staking function is the controlling of ruling spans. In controlling the ruling span the following should be considered.

- **Validity of the basic design ruling span:** The real test for the validity of the selected design ruling span occurs during the staking.

The basic design ruling span data should be suitable for the great majority of stringing sections of the lines. If in staking, the actual ruling spans are consistently found to be higher or lower than the permissible range of the basic design ruling span, it is an indication the selection of the basic design ruling span was incorrect. In this case another basic design ruling span should be selected and the basic design data modified as necessary.

- **Impact of long spans:**
  Examination of the ruling span equations shows long spans have more impact on ruling span than short spans. Therefore, control of ruling span is generally achieved by controlling the long spans. The impact of a long span can be determined by calculating the actual ruling span with, and without, the long span included. If the long span shifts the stringing section ruling span from the basic design ruling span to a higher alternate design ruling span, the alternate design data will generally be incorrect for both the long span and the remainder of the spans. Long spans are controlled by shortening the span or by isolation of the long span by dead-ending.

Sometimes in crossing rough ground there may be several adjacent long spans. In such cases it is ordinarily more economical to dead-end the conductor at both ends of the long span section and use a longer design ruling span for the entire dead-ended section. The conductor should usually be dead-ended where there is a change in the ruling span.

It may or may not be necessary to guy the structure where the conductor is dead-ended. If the structure has adequate longitudinal strength to resist the differences in longitudinal tension under all conditions of loading, guys will generally not be needed.

F. EFFECTS OF THE "WRONG" RULING SPAN

The greater the difference between the theoretical ruling span and the design ruling span, the greater will be the variation between the actual and predicted sag and tension values. The magnitude by which actual sags and tensions will differ from the predicted sags and tensions is a function of several parameters.

For unloaded conditions (no wind or ice on the conductor), the effect of variations in theoretical and design ruling spans is related to conductor temperature. Table IV-1 expresses this relationship.

TABLE IV-1
DIRECTION OF DEVIATION OF SAGS FROM PREDICTED VALUES WHEN THEORETICAL AND ASSUMED RULING SPAN VALUES ARE SIGNIFICANTLY DIFFERENT
(Applies to Unloaded Condition)

	Design S_r > Theoretical S_r	Design S_r < Theoretical S_r
Conductor temp. of condition being checked is less than temp. at which conductor was sagged.	Actual Sag < Predicted INCREASED TENSIONS	Actual Sag > Predicted INCREASED SAGS
Conductor temp. of condition being checked is greater than temp. at which conductor was sagged.	Actual Sag > Predicted INCREASED SAGS	Actual Sag < Predicted INCREASED TENSIONS

INCREASED SAGS — Bare conductor sags greater than predicted may result in ground clearance problems.

INCREASED TENSIONS — Bare conductor tensions greater than anticipated will result. Crossing clearances under other lines may be jeopardized.

This table helps explain discrepancies between measured sags and predicted sags. Potential clearance problems can also be determined.

Most distribution lines will be designed for maximum operating temperatures of 50°C [120°F] or lower, and ground clearances will be based on 15°C [60°F] sags. Consequently, it is the 15°C sag that is of interest. From Table IV-1 it can be seen that 15°C [60°F] clearances will be jeopardized if either:

- The stringing temperature was less than 15°C [60°F] and the design ruling span is greater than the theoretical ruling span;
- The stringing temperature was greater than 15°C [60°F] and the design ruling span is less than the theoretical span.

If the maximum operating temperature is greater than 50°C [120°F] then phase conductor clearances are based on the sag at the maximum operating temperature (which would be greater than the stringing temperature). As a result, clearances will be jeopardized if the design ruling span is greater than the theoretical ruling span and the line clearance is controlled by the phase conductor.

Table IV-1 can be made more general to include loaded conductor cases by replacing the temperature comparisons with ruling span sag comparisons. This change is reflected in Table IV-2.

This table is of value in predicting potential guying problems. The ruling span sag under loaded conditions often exceeds the ruling span sag to which the conductor is strung. It follows from Table IV-2 that if the design ruling span is greater than the theoretical ruling span, tensions will be less than predicted and guying should be adequate.

Tables IV-1 and IV-2 can be combined to make a "rule-of-thumb" table (Table IV-3) which will be true in the majority of cases.

Design packages should be prepared so they may be used over a range of actual ruling spans (typically 20 m [75 ft]). The extent to which this will be possible is dependent on what design ruling span and other design parameters are used. In the light loading district, when using small conductors, the practical range may be considerably longer.

As a rule of thumb, a ruling span near the low end of the desired range of theoretical ruling spans should be used as the design ruling span. From Table IV-3 it can be seen that the potential problems would be:

- Ground clearances for temperature less than the sagging temperature and;
- Guy problems.

TABLE IV-2

DIRECTION OF DEVIATION OF SAGS FROM PREDICTED VALUES WHEN THEORETICAL AND ASSUMED RULING SPAN VALUES ARE SIGNIFICANTLY DIFFERENT

	Design S_r > Theoretical S_r	Design S_r < Theoretical S_r
Conductor ruling span sag of condition being checked is less than ruling span sag at which conductor was strung.	Actual Sag < Predicted INCREASED TENSIONS	Actual Sag > Predicted CLEARANCE PROBLEMS
Conductor ruling span sag of condition being checked is greater than ruling span sag at which conductor was strung.	Actual Sag > Predicted CLEARANCE PROBLEMS	Actual Sag < Predicted INCREASED TENSIONS

INCREASED SAGS — Loaded or bare conductor sags greater than predicted may result in clearance problems.

INCREASED TENSIONS — Loaded or bare conductor tensions greater than anticipated will result. Crossing clearances under other lines may be jeopardized.

TABLE IV-3
POTENTIAL PROBLEMS WHEN DESIGN AND THEORETICAL RULING SPANS ARE DIFFERENT

Design S_r> Theoretical S_r	Design S_r< Theoretical S_r
1. Loaded and high temperature ground clearance problems.	1. Ground clearance problems for temperatures, less than the sagging temperature.
2. Excessive cold temperature bare conductor tension (uplift problems).	2. Guy tension under loaded conditions greater than predicted.

If the sagging temperature is 15°C [60°F] or less, the reduced clearances at temperatures colder than this should be of no concern. For stringing temperatures greater than 15°C [60°F], the actual 15°C [60°F] clearances may be somewhat less than predicted. However, the reduction in clearance should be well within the tolerance used for preparation of the staking table. Guy problems could result from actual design tensions being greater than predicted. However, for distribution design, this variation is typically quite small for the range of ruling spans normally used and would not result in different guying design.

The possible small error in tension can be compensated for by adding a small design tolerance to the design tensions applied to supporting structures and guys.

CHAPTER IV-6
CONDUCTOR SAG-TENSION DESIGN

A. SAG-TENSION BEHAVIOR UNDER OPERATING CONDITIONS

The sag and tension equations which have been given to this point in this design manual are valid only when the conductor is either in a steady state condition in which the length of the conductor does not change, or during a period of time sufficiently short that any change in length is negligible.

Those who work with conductors are aware that the conductor length does change and with this change there is a corresponding change in the conductor sag. Conductor changes length as the conductor temperature changes. Conductor changes length when the weight of the conductor changes due to weight of added ice or wind loads. The length of conductor changes with time as it stretches or creeps due to the tension or stress imposed on the conductor. Under actual operating conditions these changes occur continuously and simultaneously.

In selecting the conductor design to be used as a part of the line design, it is necessary to be able to predict the behavior of the conductor sags and tensions under the future operating conditions to which the line will be exposed. Conductor sags are critical to the determination of conductor clearances. Conductor tensions under maximum conditions are necessary to determine the strength requirements of the supporting structures and also of the conductor.

For a particular span length of conductor of a specific size and type, the behavior of the conductor sags and tensions is dependent on the tension placed in the conductor at the time of sagging the conductor. Therefore, the future behavior of the conductor can be controlled by controlling the initial sagging tension. At the moment of sagging, the conductor can be considered to be in a steady state, therefore the behavior can be controlled by bringing either the initial tension or initial sag to a predetermined value.

The sag and tension behavior for a dead-ended conductor span can be predicted for changing conditions of conductor loading, temperature, tension, and inelastic deformation of the conductor (creep), provided, either the conductor sag or tension, the conductor temperature, and the status of conductor creep are known at the time of sagging the conductor. Conversely, if a specific sag is desired for a specific future condition, the initial sag or tension which will produce the desired sag can be determined.

The calculations required to predict this sag-tension behavior are complicated and are usually performed with sophisticated computer

programs. The calculations involve the simultaneous application of equations for sag-tension relationships, conductor stress-strain characteristics, and change in conductor length as a function of conductor temperature.

To compute the sag-tension behavior of the conductor for a specific span length, all conductor characteristics pertinent to the calculation, the span length, conditions of loading, and one or more limiting conditions of conductor tension, are entered as input to the computer program. The conditions of conductor temperatures and loadings, for which data is needed, are also specified and entered. The sag-tension characteristics of the specific conductor are also entered. The program determines which limiting conductor tension will control the design, determines whether final sags will be controlled by the maximum tension or by conductor creep, and calculates the initial and final sags and tensions for all specified conditions. The tabulation of these results constitutes the sag-tension data for the conductor design. Alternate conductor designs can be obtained by changing the span length, the limiting tension conditions, or the conductor loading conditions. Each change in design ruling span length or controlling condition produces a different conductor design.

Sag-tension data for alternate conductor designs can be used to determine which design is most practical for a particular utility system. Once selected, the criteria for the selected data is included as a part of the basic design criteria. The selected data is then used as the basis for preparation of the detailed staking design guides.

B. SOURCES OF SAG-TENSION DATA

Most small utilities will not have available the computer hardware and software necessary to compute sag-tension data. These utilities will therefore need to acquire this data from the conductor manufacturers, consultants, or other organizations which have the necessary facilities and expertise. It is recommended that the data be obtained from an organization which uses a computer program developed by one of the major conductor manufacturers.

The conductor manufacturers will usually prepare such data and provide consultation concerning the design parameters for such data for utilities which are regular customers. Some of the manufacturers have made their programs available to utilities and consultants which have adequate facilities and qualified engineering staff.

While the manufacturers continue to provide services concerning conductor sags and tension and other information related to installation of the conductor, as a general rule, they no longer provide detailed staking design data such as stringing tables, staking tables, guying guides, or pole strength tables.

C. REUSE OF EXISTING SAG-TENSION DATA

As previously indicated, staking design guides prepared prior to 1977 are probably obsolete and need replacement. However, it is not necessarily true that the basic sag-tension data used to prepare the guides is obsolete. It is more probable that sag-tension data predating 1977 may not have data for all of the conditions needed to meet current safety and design requirements. If the data is incomplete, it is more practical to obtain a complete new set of data than to fill in the missing data. Data for the following conditions may be missing in older sag-tension data.

- High conductor operating temperature for above 50°C [120°F];
- Conductor sag data for transverse wind loadings of 290 Pa [6 lb/ft²] and 190 Pa [4 lb/ft²];
- Effect of conductor creep (inelastic deformation) used in determination of final sags.

Much of the sag-tension data prepared during the past thirty years has included the effect of creep, however this is not universally so. Generally the data will state that creep has been considered or that creep is or is not a factor. If such statements are missing it should be assumed that creep was not considered.

With the exception of the impact of creep, the characteristics of conductor as indicated by sag-tension data have not changed. The values have changed slightly because of the improved accuracy obtained by using the computer to calculate the data. Therefore, experience using designs based on old sag-tension data should be considered in requesting new sag-tension data.

Whoever is preparing the sag-tension data

should be made aware of both the good and the unsatisfactory performance of conductor designs historically used on the system. However, it must also be recognized that unless the conductor was actually installed and sagged in conformance with the design guides the historic experience may be misleading or of little value.

D. CONTENTS OF SAG-TENSION DATA

Table IV-4 is a typical example of the output of a computer sag-tension computation. For a specific conductor and preselected design ruling span, the output includes the initial and final sags and tensions for each condition of temperature and loading requested, as well as for the conditions selected to control the design.

Although several controlling conditions may be entered into the computer calculation, only the most limiting will control the design. The printout will identify which condition did control the design. In the example, the controlling tension is enclosed in parenthesis.

A separate computer output is provided for each change in design ruling span and each change in controlling tension or sag.

TABLE IV-4
SAG TENSION DATA

Ruling Span: 100 Meters   Loading District: Heavy

Design Conditions			Final		Initial	
Temp. °C	Ice mm	Wind Pa	Sag m	Tension N	Sag m	Tension N
-18.0	12.5	190.0	2.14	9728.	2.14	9728.
0.0	12.5	0.0	1.88	6718.	1.68	7502.
-30.0	0.00	0.0	0.51	5237.	0.39	6874.
-15.0	0.00	0.0	0.65	4070.	0.44	6070.
0.0	0.00	0.0	0.86	3089.	0.51	5237.
15.0	0.00	0.0	1.12	(2363.)	0.60	4384.
30.0	0.00	0.0	1.35	1971.	0.75	3560.
45.0	0.00	0.0	1.46	1814.	0.94	2824.
50.0	0.00	0.0	1.50	1775.	1.01	2618.
60.0	0.00	0.0	1.58	1687.	1.18	2256.
75.0	0.00	0.0	1.70	1569.	1.43	1853.
100.0	0.00	0.0	1.90	1402.	1.80	1471.
15.0	0.00	190.0	1.27	2854.	0.78	4629.
15.0	0.00	290.0	1.40	3275.	0.94	4874.

CHAPTER IV-7
CONDUCTOR DESIGN TENSIONS AND TENSION LIMITS

A. SAG-TENSION DATA TENSION LIMITS

For a given design ruling span, conductor size and type, and loading conditions, the conductor design is established by the specified tension limits. Any number of tension limits may be specified, but only one will control the design. If the temperature and loading conditions are held constant and data prepared for other design ruling spans, the control of the design may possibly shift to another tension limit.

Tension limits may be specified for any of the following reasons:

- NESC conductor limits are mandatory;
- For certain types of conductors the conductor manufacturers or the industry establishes maximum recommended limits more restrictive than the NESC;

- To coordinate with strength capabilities of the dead-end supporting structures;
- To coordinate with strength of guy assemblies;
- To coordinate with strength of pin type insulator assemblies on small angle structure assemblies;
- To alleviate uplift design problems on short span construction;
- To coordinate sags between conductors supported on the same structures;
- To reduce probability of aeolian vibration damage.

During the early years of rural electrification most conductors were small and in most cases the conductors were designed in conformance with one of the first two tension considerations listed above. Copper and copperclad-copper conductors were generally designed to the NESC limits. Standard ACSR conductors were designed in accordance with tension limits recommended by the conductor manufacturers and were generally uniform through the industry.

With an increasing use of larger conductors up to 795 kcmil sizes, shortened spans, added sag coordination problems introduced by the 1977 NESC, and more experience with conductor fatigue, it is advisable to examine the possible need for application of other tension limits. This chapter discusses some of these additional considerations. The discussion pertains to standard ACSR conductors of (6/1) and (26/7) stranding unless otherwise indicated. A discussion concerning tension limits to control aeolian vibration is included in Chapter IV-8.

B. NESC TENSION LIMITS

The NESC tension limits are given in Part II of this design manual. These limits are generally considered inadequate for standard ACSR and all aluminum conductors. They may be adequate for some of the newer self dampening conductors and other designs less vulnerable to aeolian vibration fatigue. For such conductors the recommendation of the manufacturer should be obtained and not exceeded.

C. RECOMMENDED PRACTICE TENSION LIMITS

Table IV-5 provides conductor tension limits recommended for use on rural distribution lines. The tension limits given for ACSR conductors are in general conformance with conductor industry recommendations. The limits given for all-aluminum conductors conform to the recommendations of REA Bulletin 80-5, Conductor Installation for Electric Distribution Lines, and REA Bulletin 62-1, Design Manual for High Voltage Transmission Lines.

The values given for 1-phase lines may also be used for small conductor 3-phase tap lines. Small conductor lines are those with 1/0 and smaller phase conductors.

D. TENSION LIMITS BASED ON DEAD-END ASSEMBLIES

With distribution conductors up to 795 kcmil in size, it is soon recognized that for some conductors, the tension limits given in Table IV-5 may be larger than the rated loads given for dead-end insulators in Part III of this design manual. Table IV-6 gives the percent of rated conductor strength permissible for the dead-end insulator assemblies. The ANSI 52-1 insulator is standard for 12.5/7.2 kV construction. The ANSI 52-4 insulator is standard for 34.5/19.9 kV construction and both are used for 24.9/14.4 kV construction. The ANSI 52-6 is a transmission insulator and requires special hardware.

E. TENSION COORDINATION WITH OTHER STRUCTURE COMPONENTS

With the large conductors, problems similar to the dead-end insulator condition above, may be encountered with pin type and post type insulator assemblies, guy and anchor assemblies, and other structure components. The coordination requirements may be more restrictive than the limits imposed by the dead-end assemblies and need to be checked.

F. CONTROLLING CONDUCTOR DESIGN WITH SPECIFIED SAGS

Sag-tension computations are usually controlled by specifying tension limits. However, it is possible to start with a desired sag condition. This procedure is used to coordinate the sag of one conductor with that of another for which the sag is known, or for other design problems where a specific sag is desired.

Most sag-tension computer programs have sag matching capabilities. However, the case can generally be run for only one span length

TABLE IV-5
RECOMMENDED MAXIMUM TENSION LIMITS
IN PERCENT OF CONDUCTOR RATED STRENGTH

	ACSR Conductors		All-Aluminum Conductors	
	3-Phase Lines	1-Phase Lines	3-Phase Lines	1-Phase Lines
Initial Unloaded	33.3%	33.3%	30%	30%
Final Unloaded	25%	25%	20%	20%
NESC Loading District	50%	60%	50%	50%
NESC Extreme Wind	70%	80%	60%	80%
Extreme Ice	70%	80%	60%	80%

Loading Conditions: As required for NESC Tension Limits.
Extreme Ice Loading: Based on local experience with no wind.
Temperature Conditions:
Heavy Loading District: -20°C [0°F]
Medium Loading District: -10°C [15°F]
Light Loading District: 0°C [30°F]
The above tension limits for unload conditions should be reduced in areas prone to aeolian vibration fatigue of conductors.

TABLE IV-6
MAXIMUM CONDUCTOR TENSION LIMITED BY
REA DEAD END INSULATOR ASSEMBLIES

Conductor Size ACSR		ANSI Insulator Class		
		52-1	52-4	52-6
kcmil	Stranding	Percent of Rated Conductor Strength		
795	(26/7)	16.1	24.2	40.3
636	(26/7)	19.8	29.8	49.6
556.5	(26/7)	22.1	33.2	
477	(26/7)	25.6	38.5	
336.4	(26/7)	35.5		
266.8	(26/7)	49.2		
795	(45/7)	22.6	33.9	
636	(18/1)	31.8	47.8	
556.5	(18/1)	36.5		
477	(18/1)	42.4		

Tension values not listed are in excess of 50%.

and all other tension limits should be eliminated so that there is only one limiting condition.

If the program does not have sag matching capability, the tension can be calculated manually by using the parabolic sag and tension equations in Chapter IV-4. For the given steady state condition, start with the sag, first calculate T_h, then T_r, and finally T_a. Use T_a as the only tension limit for the sag-tension computation. The results are checked to determine if any required tension limits are exceeded.

G. REQUESTING SAG-TENSION DATA

When requesting sag-tension data from a conductor manufacturer or some other organization be sure to provide complete information on what is needed. If not sure what is needed, contact the organization to find out. Most organizations providing such services have data request forms which when completely filled in will provide the information required to properly calculate the requested data. Example data request forms are provided in Appendix E.

Sag-tension data, as a minimum, is needed to calculate NESC clearance requirements for the following conditions:

- 15°C [60°F], bare conductor, no wind, final sag;
- 15°C [60°F], bare conductor, 290 Pa [6 lb/ft²] wind, final sag;
- 15°C [60°F], bare conductor, 190 Pa [4 lb/ft²] wind, final sag;
- 50°C [120°F], bare conductor, no wind, final sag;
- Highest operating temperature, bare conductor, final sag;
- 0°C [32°F], NESC ice coating for loading district, no wind, final sag.

The following additional sag-tension data may be needed to prepare staking design guides:

- Extreme wind loading condition for local area at 15°C [60°F], initial tension;
- Minimum initial sag condition required for uplift calculation. Temperature based on local conditions, bare conductor, no wind, initial sag.

Additional temperature conditions are needed to prepare stringing sag tables. The usual practice is to obtain temperature data in 10°C or 15°F increments. Intermediate temperatures are interpolated. The data is needed through the range of temperatures at which the conductor might be sagged.

The request for sag-tension data should indicate that conductor creep should be considered as a factor in determining final sags. The request should also indicate the desired range and increments for alternate ruling span lengths. For metric line design, span lengths in increments of 10 meters, and for customary unit design, increments of 25 feet are recommended.

H. METRIC CONDUCTOR DATA

It is necessary to caution the reader of possible discrepencies in the manner which metric data for conductor may be provided.

Historically conductor manufacturers have converted customary conductor weights per unit foot to kilograms (mass) per unit meter. This manual and REA Bulletin 62-1, Design Manual for High Voltage Transmission Lines, as well as other recent design manuals based on the SI Metric system of units have converted the weight to newton (force) per unit meter. The values differ by a factor of 9.807, the newton values being the larger.

The manufacturer's practice is correct when the intent is the measurement of mass per unit length of conductor. However, the designer is concerned with the force which the conductor imposes on the structure.

This discrepency is the result of a difference in the manner weight, mass, and force are commonly used in the customary system as compared to the SI Metric system. For those who are unfamilar with these differences a brief explanation follows.

In the customary system of units, weight is the measurement of force. The unit of measurement is the pound which equals the force required to support the standard pound mass against gravity at sea level. Loosely, the term weight is used to represent both force and mass. In the latter case, weight meaning the mass which would exert a force or weight of one pound.

In the SI Metric system of units, the unit of force is the newton which is the force (weight) exerted by the gravitational pull of the earth on one kilogram of mass at sea level. Historically the term kilogram has been applied to both kilogram mass and kilogram force although the values differ by a factor equal to the accelera-

tion of gravity. The newton is used to replace the older term kilogram-force to clarify this difference.

Thus when one pound of weight (force) is converted to metric, the correct unit is the newton. When one pound of mass (meaning the mass which would exert one pound force) is converted to metric, the correct unit is the kilogram (mass). At sea level one kilogram exerts a force of 9.807 newtons. Although the acceleration of gravity varies geographically and with altitude, for practical applications the conversion factor of 9.8 m/sec^2 can be used wherever lines are being designed.

Therefore if the conductor data is furnished in kilograms per meter, the data must be multiplied by 9.8 m/sec^2 to convert the data to newtons per meter before using the data in force equations.

CHAPTER IV-8
CONTROLLING AEOLIAN VIBRATION

A. CONDUCTOR VIBRATION

When selecting the design criteria for an overhead distribution line, some consideration should be given to the possible need for a conductor design which will minimize adverse effects resulting from wind produced conductor vibration. Almost every rural distribution line will at times be subjected to aeolian vibration. The real concern is not whether the conductor vibrates but rather whether the amplitude of the vibrations and the frequency of occurrence of the vibration will be such as to cause fatigue failure of the conductor or structure components within the anticipated useful life of the line.

There are many factors that play a more or less prominent part in the aeolian vibration characteristics of a line. Some of the variables include:

- Conductor design tensions;
- Conductor tensions at cold temperatures;
- Conductor size;
- Conductor material;
- Conductor type;
- Wind velocity;
- Wind turbulence;
- Terrain and vegetation;
- Height of conductor above ground;
- Direction of prevailing winds;
- Self damping characteristics of the conductor;
- Method and devices of attaching conductor to supports;
- Characteristics of any damping devices used in the construction.

With all of these variables, it is extremely difficult to establish one set of guidelines applicable to all conductor designs needed for a single distribution system.

The purpose here is to provide general information concerning aeolian vibration that might be helpful in evaluating whether a vibration problem might exist on a particular line design.

Much has been published concerning the theory of aeolian vibration. However, this literature provides very few of the specific values needed for selecting the design criteria for distribution lines. Very few small utilities, or the consultants who serve them, have the expertise, computer software, or the bank of data needed to make the type analysis required to determine the most practical conductor design to minimize the probability of vibration damage for a specific line. When it is suspected that conditions might exist that could cause excessive vibration damage, it is suggested that assistance be obtained from the manufacturer of the conductor.

B. AEOLIAN VIBRATION THEORY

When a comparatively steady wind blows across a conductor under tension, vortices are detached at regular intervals on the lee side, alternately from the top and bottom of the conductor. Each detachment is accompanied by a minute, vertical force. The conductor is thus repeatedly subjected to forces alternately impressed from above and below. The frequency of the forces increases with increasing wind velocity and with decreasing conductor diameters.

If the frequency of the forces corresponds approximately to the frequency of a mode of vibration of the span, the conductor will tend to

vibrate in many loops, in a vertical plane. The forces impressed by the wind on the conductor produce traveling waves that move away from the points of application of the forces toward the ends of the span. At the span end the traveling waves are reflected and are superimposed on the inwardly traveling waves, thereby producing standing waves, which have frequencies that are multiples of the fundamental frequency of the entire span. Each wave stores part of the energy it receives from the wind during the course of its travel, in the form of increased amplitude; the crest becoming higher and the trough deeper. The balance of energy received from the wind is dissipated primarily by friction between the conductor strands as the conductor is flexed by the passage of the wave.

When a wave reaches the end of an undamped span and is reflected, neither its amplitude nor the energy stored in it is significantly reduced by the reflection. During its subsequent travel, the wave acquires more energy and greater amplitude from the wind-induced vortices until an equilibrium amplitude is reached with dissipation in the conductor of subsequent input energy. This energy balance may be reached at an amplitude that is damaging to the conductor or potentially damaging to supporting structure components.

C. FACTORS AFFECTING VIBRATION

There are a number of factors which determine the vibration characteristics of a line.

Basically, for a given conductor size and construction, span length and tension in tandem have the primary effect on a line's susceptibility to aeolian vibration. The amount of energy imparted to a conductor varies directly with the span length. The longer the span, the more wind-induced energy the traveling wave picks up. With increasing conductor tension, the tendency of a conductor to vibrate increases rapidly as its self-damping ability, the frictional interaction between strands, is reduced.

If the terrain is rough, the winds are apt to be more turbulent and the line subject to less vibration. If the line runs through a wooded area, or runs parallel to the prevailing winds, vibration will generally not be a problem. In most places, winds in excess of about 15 mph (24.14 km/hr) will be so turbulent they will not produce vibration. However, in level terrain or long river crossings, vibration-producing winds have been reported up to 35 mph (56.32 km/hr).

Structure type does have a minor effect on vibration characteristics of a line. Damping properties of the construction material influence the tower's effect on conductor vibration. Wood structures tend to suppress aeolian vibration of the conductor while metal poles do not. Higher poles with greater conductor ground clearance generally mean a greater exposure to vibration-producing winds, since turbulence lessens with height above ground. It is this factor that has resulted in a minimum of damaging aeolian vibration to rural distribution lines; the conductor being relatively close to the ground.

Although there are several types of conductor ties and supporting clamps on the market, so far there is no such device that does a significant job of damping conductor vibration.

Armor rods reinforce the conductor and do a small amount of damping, thus providing a minor degree of protection against aeolian vibration. This protection has proven to be adequate for the majority of rural distribution lines.

In the past if lines of a given design have not had aeolian vibration problems with the use of armor rods, new lines of the same design (ruling span, conductor, pole height, wind exposure) should not need additional protection against aeolian vibration. Proposed new lines with longer ruling spans, higher conductor tension or greater pole height may require additional aeolian vibration protection.

If damping in addition to that provided by armor rods is found necessary, some type of impact damping device should be considered. Stockbridge type dampers when properly sized and applied, generally provide adequate protection for any size distribution conductor. Spiral type and other less costly impact dampers may provide adequate protection for small size ACSR and all-aluminum conductors.

D. SYSTEM EXPERIENCE WITH AEOLIAN VIBRATION

From the preceding discussion it is seen that vulnerability to vibration problems varies with both conductor design used and the type of geography of the area in which the line is located. One of the best guides to use in determining the degree of vulnerability is historic experience with existing designs used on the system. The utility is generally aware as to whether there have been no fatigue problems, moderate problems, or severe problems. If there

have been problems the utility should be aware which line designs have had vibration damage and which have not. This knowledge can be very useful in selecting criteria for new lines. This knowledge can be of use in both modifications to existing designs and for new designs that have some relationship to existing designs. Certain design changes will decrease and others increase probability of vibration fatigue damage.

The following paragraphs provide guides which may be of assistance in determining whether a change from an existing design will increase or decrease probability of aeolian vibration. Each of these guides assumes that all other variables remain constant.

Increasing the span length will increase probability of vibration damage. Thus, for any conductor design, or for any design ruling span, the long spans in the line section will be more vulnerable to vibration damage than the short spans.

For a given sagging temperature, increasing the sagging tension will increase probability of vibration.

The designer should be aware that changing the ruling span without changing the tension design limits will result in a change in the sagging tension.

When it is desired to apply stringing tension experience with a particular conductor size and type to another conductor size of the same type, stranding, and aluminum-to-steel ratio, conductor stress should be used rather than tension. Stress is equal to the tension divided by the cross-sectional area of the conductor.

Considering both size and stress as factors, if the size of a particular conductor type is increased without changing the stress the probability of vibration damage will generally decrease. If the size is reduced, the probability of damage will generally increase.

ACSR conductors with higher percentages of steel have better self damping characteristics than ACSR conductors with smaller percentages of steel. ACSR conductors have better self damping characteristics than all-aluminum conductors. Therefore, there may be need for reducing the design sagging stress when making such substitutions.

E. OTHER DESIGN GUIDES

Caution should be used with designs or design guides that have been used on other systems or from similar sources unless it is certain that all conditions of design and geography are nearly identical. A design which is suitable in one area may not be adequate in another area where conditions differ.

Generally conductor designs should not be used in cases where the design tension limits exceed those given in Table IV-5. This guide is one that has been used for the great majority of existing rural distribution lines. The design is more restrictive than the NESC and in most areas of the country has worked reasonably well. However, the design may be marginal or inadequate in areas subject to severe aeolian vibration incidence. The guide was originally developed as a guide for optimum self-damping of conductor. This does not mean that these conductor design limits will eliminate conductor vibration but rather that in most types of terrain the vibration will not generally cause fatigue failure. In exposed areas and for long spans it may be necessary to add commercially available damping devices for additional damping.

Generally, for span lengths common to distribution lines, aeolian vibration damage will be eliminated if the design initial tensions at 15°C [60°F] are at or below 12 percent of the ultimate strength of the conductor. In some cases the sags produced by these low stringing tensions may be economically impractical, especially where long span construction is desired. On the other hand, such designs might be entirely feasible for short span construction. In some cases the design limitations of the supporting dead-end structures may result in stringing tensions which may be close to these low values. If the design is such that for most spans in the line there will be excess ground clearance, a small increase in sag may reduce the stringing tensions close to these values.

The economics of overhead rural distribution line construction will usually indicate that the spans be as long and the sags as small as practical. On the other hand, the two conductor design variables that have the greatest effect upon the vibration characteristics of a line are conductor tension and span length. To alleviate the probability of aeolian vibration, the spans should be as short as possible and the tension and sags as slack as possible. It is obvious that in those areas where the lines are vulnerable to vibration-producing winds some compromise needs to be made between these opposing design factors.

F. ASSISTANCE FROM CONDUCTOR MANUFACTURERS

After considering the previous information and guides, if there is still concern regarding possible damage from aeolian vibration damage, it is suggested that the conductor manufacturer be contacted for advice. A typical request form has been provided in Appendix E. The particular manufacturer may have a form which they prefer to use; however, the typical form indicates the type of information which will be needed.

In providing the requested information be sure to give any limitations for maximum design tension that might be imposed by the supporting structures.

Some weather data for selected locations is available in the Appendices of REA Bulletin 62-1, Design Manual for High Voltage Transmission Lines. However, if the closest location given is not typical for the particular system, define the specific area. The manufacturer probably has more complete weather data than provided in Bulletin 62-1.

Information concerning previous vibration problems on the system may also be of value. However, the information may be misleading if the conductor was not actually installed to the sags or tensions indicated by the design criteria.

CHAPTER IV-9
CONDUCTOR HIGH OPERATING TEMPERATURE

A. ESTIMATING OPERATING TEMPERATURES

The NESC requirements and probability of conductor high operating temperatures are discussed in Chapter II-3.

Although conductor high operating temperature conditions will be rare on most rural distribution systems, it should be examined.

Figure IV-2 shows the relationships between ambient air temperature, conductor operating temperature, and conductor current for a range of ACSR conductors. The charts indicate that there is a possibility for some lines to exceed 50°C [120°F] operating temperatures.

These charts can be used to estimate conductor high operating temperatures for known or estimated emergency conductor currents. Table IV-7 provides conversion factors to be applied to the currents of Figure IV-2 to convert the currents to three phase kVA loads at 12.5/7.2 kV, 24.9/14.4 kV, and 34.5/19.9 kV line voltages.

TABLE IV-7

MULTIPLICATION FACTORS TO CONVERT CURRENTS TO THREE-PHASE kVA

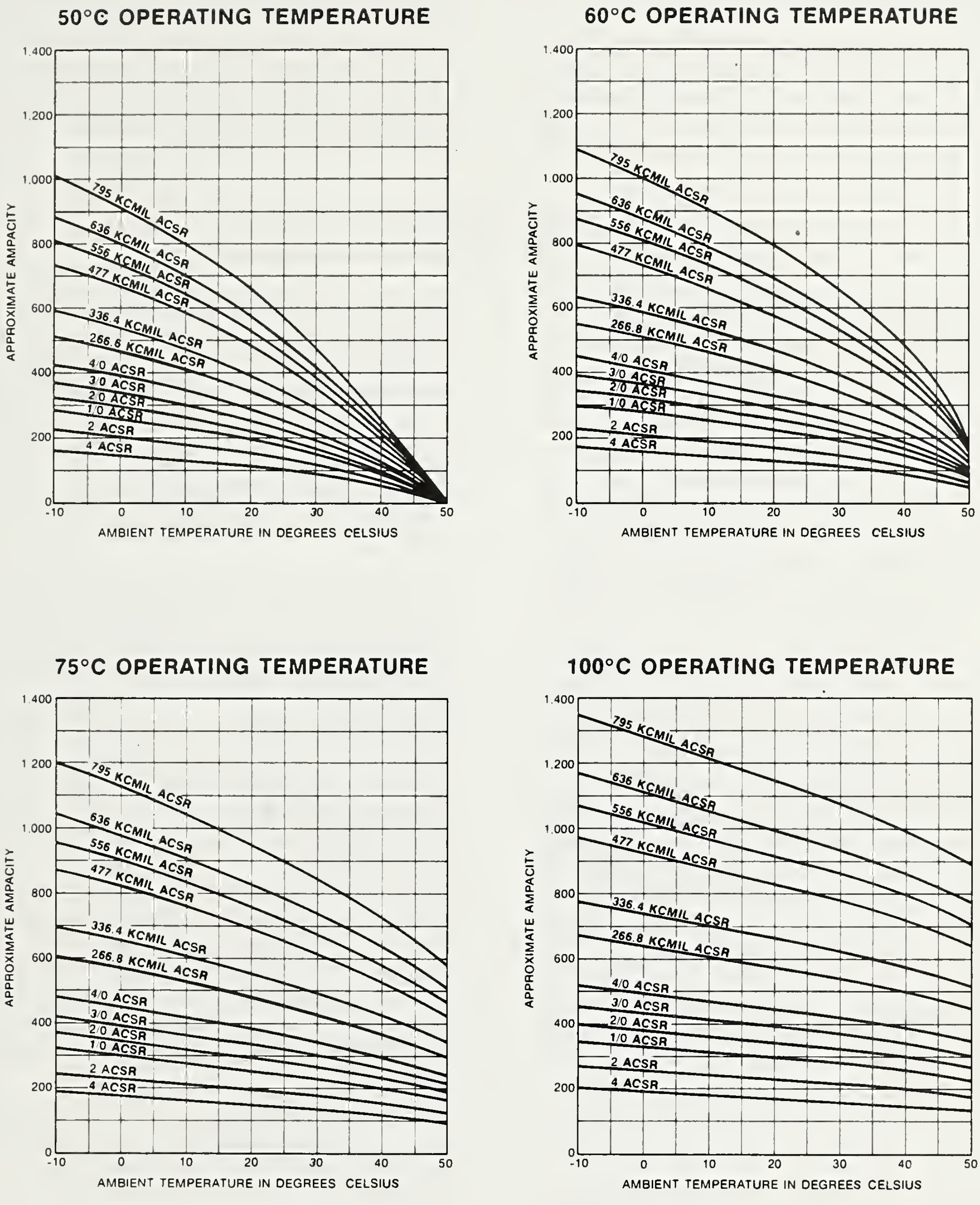
Line-to-Line kV	Factor
12.5	21.65
24.9	43.13
34.5	59.76

B. IMPACT OF HIGH CONDUCTOR TEMPERATURES ON LINE DESIGN

Where the neutral conductor controls the staking table design by several inches, as is the case with REA type C1 construction when used under the "other land" clearance rule, some capability for higher operating temperatures is inherent in the design. Under these conditions, ACSR conductors will generally be able to operate over 60°C without violating the code, provided the spans are not long. Under these conditions, the phase conductor will usually sag more than the neutral and will eventually control the clearance as the spans increase in length. The methods given in Part V for preparation of staking tables include provision for these conditions.

Where the phase conductor controls the staking table design, if high-operating temperature design is required, the required temperature will have to be determined and used in the preparation of the staking table. REA type C9 construction is of this type, and C1 construction is also when used with the "along-the-road" clearances.

Where there is a phase conductor located above the neutral, the span length may be limited by the conductor to neutral clearance requirements of NESC Rule 235C. Span limitations due to these conditions are determined by methods given in Part V of this design manual.



CONDUCTOR AMPACITIES

FIGURE IV-2

C. BEHAVIOR OF CONDUCTOR TYPES AT HIGH TEMPERATURES

The previous analyses are based on the use of ACSR conductors of (6/1) and (26/7) stranding. For circuits which require high-temperature design, the designer should be aware that all-aluminum conductors have different sag characteristics under high-temperature operation than ACSR conductors. ACSR conductors of different ratios of aluminum to steel will also behave differently at high operating temperatures. Coordination of conductors at high-operating temperatures is discussed in Chapter IV-10.

CHAPTER IV-10
COORDINATION OF CONDUCTOR DESIGNS

A. BASIC COORDINATION CONCEPTS

One other factor that needs consideration in selecting conductor sag-tension design, is the coordination of sags between the various sizes and types of conductors located on the same supporting structure. Other than for the phase conductors of the same circuit, it is often necessary to use different stringing sags for the conductors in order to achieve the desired coordination. In this case it is necessary to select the sag of one conductor as the base and coordinate the sag-tension design of the other conductors with the base conductor.

The most common sag coordination problems occur between phase and neutral conductors when the phase conductor is located above the neutral conductor on the same pole line. This discussion is limited to the coordination between the center phase conductor of an REA type C1 structure and the neutral conductor of the same circuit. The discussion can be adapted to other conductor coordination problems.

Other than satisfying NESC requirements, there are no "hard and fast" rules for conductor sag coordination. The designer would like to have a conductor design which would satisfy the four coordination goals listed below. Unfortunately, these are conflicting, therefore only one can be selected, or compromises made.

- Provide simplified sagging: phase and neutral initial sags are matched.
- Provide best appearance: phase and neutral final sags are matched at normal operating temperatures.
- Provide maximum level ground span: neutral sag is based on maximum allowable tension.
- Eliminate span limitations: phase and neutral sags coordination is not a span limiting condition for the great majority of spans.

For convenience of the sagging crew, it is desirable for the phase and neutral conductor to be sagged to the same value. However, unless the conductors are identical, the sags will differ for all future conditions. The magnitude of the difference will depend on the conductor material and loading conditions. It is still necessary to obtain sag-tension data for both conductors in order to examine all limiting conditions.

Historically, it was a common practice to match sags at normal operating conditions, i.e., at 15°C [60°F] temperatures with the conductor at final sag conditions. This method of coordination generally provides the best appearance. Prior to 1977, NESC vertical separations were determined at this condition. The 1977 NESC changed the determination of vertical clearances to 15°C [60°F] for the neutral and for the phase conductor to 50°C [120°F] or the maximum operating temperature, whichever is greater. Under the current NESC rules, this coordination method may be too limiting for certain combinations of conductors when long span construction is used. For this coordination method, the phase conductor will have greater sag than the neutral. The difference will increase in proportion to the square of the span length.

When the preceding coordination methods are found to be too limiting on span length due to conductor separation, it is necessary to:

- Either increase the separation at the supports;
- Increase the neutral conductor sag at the condition for determing the vertical separation, or
- Decrease the phase conductor sag as required to obtain an acceptable span limit.

The first two corrective methods will reduce

the permissible level ground span and may require taller poles. The last correction method will cause an increase in phase conductor tension which may become a limiting condition.

When the primary concern in designing the line is to optimize the level ground span, the sag coordination procedure starts with the neutral as the base conductor. The maximum design tension is selected which will satisfy the requirements discussed in the previous chapters. The phase conductor sag-tension design is selected to coordinate with the neutral. If the resulting design exceeds any tension limits or if the conductor separation is too limiting, the basis for the coordination design shifts to the phase conductor. The phase conductor tension is reduced as needed and the neutral conductor is coordinated with the phase conductor.

Generally, sag coordination is more of a problem for long span construction than for short span construction.

B. IMPACT OF CONDUCTOR MATERIALS

The coordination of the phase and neutral conductor may have some impact on the choice of type and size used for the design. The two conductor characteristics that are of importance in sag coordination are the rated stress (rated strength divided by the cross sectional area) and the temperature coefficient of expansion (the change in length per degree change in temperature). Following are factors concerning the above which should be considered in selecting conductor materials for a coordinated design.

- **Conductors of like composition:**
  All conductors of like composition will have essentially the same rated stress. For example, all ACSR conductors with (6/1) stranding have essentially equal rated stresses, the stress-strain characteristics are alike, and the temperature coefficient is the same. ACSR conductors with (26/7) stranding will have equal characteristics and because the ratio of aluminum to steel is equivalent to ACSR (6/1) strand conductors, the characteristics of these two types will be very similar.

Sag coordination is usually the easiest for conductors of like composition. Without ice or wind loads they will creep to the same final sag. When loaded to NESC ice and wind loads a small conductor will stretch more than a large conductor because it carries a larger ice load in proportion to its area than does the large conductor. Thus, if the conductors are sagged to the same initial sag, the final sag of the smaller conductor will be greater than the larger conductor if the final sag is a function of the loaded condition. If the final sag is a function of creep, the final sags will be very nearly the same.

- **Conductors of unlike stress characteristics:**
  Sag coordination can sometimes be a problem if the upper conductor has lower rated stress than the lower conductor. Generally conductors with lower rated stress will strain more with the same applied stress, will creep more, and will have more permanent stretch. Thus, if the conductors are sagged to the same initial sag, the one with the lower rated stress will usually have a greater final sag. It is usually desirable for the upper conductor to have a sag equal to or less than the lower conductor.

For this combination, one danger that should be examined is what may happen during an extreme ice storm. Under heavy ice loads, the phase conductor may sag into the neutral conductor.

- **Conductors of unlike coefficients of expansion:**
  Aluminum has a larger coefficient of temperature expansion than does steel. Therefore, an all-aluminum conductor will expand more than an all-steel conductor for each degree of increase in temperature. The behavior of ACSR conductors will vary with the ratio of aluminum to steel in the conductor. As the temperature rises the load carried by the aluminum strands transfers to the steel and at some temperature all the load is carried by the steel. The sag is then a function of the coefficient of expansion of steel and the stress applied to the steel strands. For (6/1) and (26/7) strand ACSR conductors this transfer occurs at approximately 40°C (100°F). For (18/1) strand ACSR this occurs at approximately 75°C (167°F).

At high temperatures the applied stress is small, therefore the sag is more a function of expansion due to temperature than to stress. Thus the ACSR conductors with large aluminum-to-steel ratios will sag more at high temperatures than will ACSR conductors with lower ratios. When using all-aluminum and ACSR (18/1) phase conductors at high operating temperatures, the phase to neutral coordination may be a problem whether the conductors are of like or unlike composition.

C. DESIGN COORDINATION

The preceding sections and chapters have identified conditions which may cause sag coordination problems. A problem will actually exist only if the conductor design causes a limiting condition which is less than desired or needed for a practical line design. The only way to determine this is to prepare a design and check the resulting limiting conditions. The procedures are discussed in Part V of this design manual.

CHAPTER IV-11
BASIC STRENGTH REQUIREMENTS

A. STRENGTH REQUIREMENTS OF STRUCTURES

The mechanical strength requirements of an overhead line supporting structure are determined with the structure in an overloaded condition. The basic external design loads supported by the structure are multiplied by design overload capacity factors to obtain the value of the forces used in determining the required strength of the structure and structure components.

The external loads supported by the structure consist of the wind on the exposed surfaces of the structure and the resultant tension of each conductor span attached to the structure. These loads continually vary and are functions of the weather, initial stringing tensions placed in the conductors, and status of permanent stretch in the conductors. It is therefore necessary to identify the specific conditions of loading for which the structures are to be designed and the specific values of overload capacity factors which are to be applied. It is also necessary to resolve the loads into three-dimensional force vectors as the overload capacity factors differ for longitudinal, transverse, and vertical loading of the structure.

There is a close interrelationship between the selection of the external design loads to be used in design of the structure and the selection of design tensions for the conductor. The structure must be designed to support the conductor loads and at the same time the conductor loads must be limited so that the imposed forces do not exceed the capacity of the weakest component of the structure.

The following sections of this chapter discuss the selection of these basic design loads and the corresponding design overload capacity factors.

The application of the loads and overload capacity factors in the determination of the required strength of guyed and unguyed structures is demonstrated in Part V of this design manual.

B. BASIC CONDUCTOR LOADS ON THE STRUCTURE

In preceding discussions of the conductor span it was shown that the tension varies throughout the span. The conductor load that the structure supports is the resultant tension of the conductor at the point of attachment to the structure. The value of the resultant tension of the conductor and the angle at which it is applied to the structure will vary with the conditions of conductor loading. In order to design the structure, it is necessary to resolve the value of the tension into longitudinal, transverse, and vertical force vectors.

This appears to be a complex problem since the resultant tension and angle at which the conductor approaches the structure are unknown. Actually, the solution is simple and for a specific condition of conductor loading the values can be derived from the conductor sag-tension design data.

A review of the equations for the level parabolic conductor span shows that the longitudinal tension of the conductor is equal to the horizontal component of tension (T_h). The vertical component (T_v) is equal to the loaded weight of the conductor from the point of attachment to the low point of the sag, and for a level span, is equal to the weight of the conductor in one-half the span. Likewise, any transverse component of tension (T_w) due to blowout of the conductor is equal to the wind force on one-half of the conductor span.

For a specific condition of loading the values of the conductor weight plus any ice, and the wind force per unit length of conductor are the same values as used for input to the sag-tension

computations. Therefore, the vertical and transverse force vectors are obtained by multiplying these values by one-half the maximum span length for which the structure is designed to support.

The conductor tension given by the sag-tension data for a specific condition of loading is usually the average tension of the conductor span. Equations have been given to calculate the horizontal tension from the average tension; however, for distribution spans the difference is very small and it is common practice to use the average tension as the longitudinal tension value. This substitution of data simplifies the computation and provides a slightly conservative result.

In establishing the basic design criteria for structure loading, the loads applied to the structure, as a minimum, should satisfy the requirements of the NESC as given in Section 25 and discussed in Chapter II-10 of this design manual. The designer needs to make several judgements which include:

- Selection of the maximum wind span and weight span for which the structure is to be designed;
- Determination of the need for any ice or wind loadings in excess of NESC requirements due to local weather conditions.

The basic design loads selected for design of the structure should be listed as part of the basic design criteria for the line.

C. WIND LOADS ON THE STRUCTURE

In addition to the wind on the conductor which is transferred to the structure as a vector component of the conductor resultant tension, the NESC also requires that the design of the structure include the wind load on the exposed surface of the structure. The wind loading used should be the same force per square meter or foot as used in determining the wind force on the conductors. The direction of the wind is taken as that which is most critical to the design of the structure. The critical direction of loading is discussed in Part V of this design manual.

D. OVERLOAD CAPACITY FACTORS

The strength of the structure is determined with the structure overloaded. Overload capacity factors are applied to the basic design external conductor and weather loads to obtain the values of force used to design the structures.

The NESC specifies minimum overload capacity factors which are to be applied to certain grades of construction. The grades of construction are defined in Section 24 of the NESC and are discussed in Chapter II-9 of this design manual. The overload capacity factors are given in Section 26 of the NESC and are discussed in Chapter II-11 of this design manual. The structures should be designed to these requirements as a minimum.

REA Bulletin 40-7, National Electrical Safety Code, requires that REA-financed rural distribution lines be designed to meet or exceed the requirements for NESC Grade C construction as a minimum and to meet the NESC requirements where these exceed Grade C.

As a general rule the overload capacity factors required by the above will be satisfactory for the great majority of rural distribution lines.

Some lines warrant special attention for reasons of safety or reliability. Main feeder lines that serve hospitals, manufacturing processes vulnerable to service interruptions, large numbers of consumers, etc., may have reliability requirements as high as that needed for the transmission lines serving the distribution substations. In such cases it may be desirable to increase the overload capacity factors to Grade B construction levels. Other lines may warrant reliability levels somewhere between Grades B and C. Such design decisions should be indicated in the design criteria for the line.

In the design of overhead lines the overload capacity factors are indicative of the safety and reliability of the line. Where increased strength is required because of unusual local weather conditions, this modification should be made to the condition of loading. Where increased strength is desired for increased safety or reliability, the modification should be made to the overload capacity factor.

E. STANDARDIZED DESIGN LOADS

It is common practice to design the structures and structure components using longitudinal tension values taken directly from the conductor sag-tension data as discussed previously. Under certain circumstances there are advantages to using values for structure design which will cover a range of conductor design tensions.

A typical example where this concept may be quite practical is the design of a line where the topography and other controlling factors are such that several different design ruling spans will be necessary. It will be quite probable that the conductor design tensions will differ for each design ruling span even though the conductor designs for each ruling span are based on the same set of conductor tension limits. In such a case it will be necessary that the design data include stringing sag data and other conductor data for each of the design ruling spans. However, for the small differences in design tensions, it becomes quite impractical to prepare separate structure computations, guying computations and guides, pin strength data, and similar guides for each design ruling span. It becomes more practical to base all of these structure computations and guides on one structure design loading value suitable for the entire range of conductor design tensions. What is usually done is to use a rounded value of tension slightly higher than the largest conductor design tension in the series of design ruling spans, and to identify this value as the basic structure design tension.

This concept can be carried even further for such items as dead-end guying guides. If such guides are prepared in rounded increments of longitudinal strength, the guide can be used for any conductor size or type for which the conductor design tension falls within the specified tension increment.

PART V
PREPARATION OF STAKING DESIGN GUIDES

INTRODUCTION

The complete design of an overhead rural distribution line requires a multitude of solutions to design problems. The staking engineer completes the line design during the staking and it become the staker's responsibility to perform any computations necessary to complete the design. If many computations remain, the staker may end up spending more time doing computations than performing the normal field staking functions. This will be especially inefficient if it causes other members of the staking crew to be delayed in the performance of their work.

A solution to this problem is to prepare as many of the design computations as possible in advance of the staking. The need to perform exact calculations for individual structures and spans can be nearly eliminated by the preparation of well-organized staking design guides. Examples of solutions to design problems are prepared using regular intervals for the variables. The data from these solutions is presented in graphical or tabular form which can be easily interpreted or interpolated. The staker can then essentially read the solution to many of the design problems rather than calculate the answer.

All of the individual design guides and other design information which will be useful for staking a specific line design should be organized and packaged into an easy-to-use staking design guide booklet for use by the staker.

This part of this design manual focuses on the content of the staking design guide package and sets forth methods for preparing some of the more complicated elements of the package.

CHAPTER V-1
CONTENTS OF THE STAKING DESIGN GUIDE

A. PURPOSE OF THE STAKING DESIGN GUIDE

The purpose of the staking design guide package is to provide in one unit, all of the information and data prepared for a specific line design which will be useful in the staking of a line. Since much of the information may also be useful to the construction supervisors and inspectors, it is recommended that stringing and sagging guides and other data needed during construction be included. One guide package can then be used by both staking and construction personnel.

The package serves as a permanent record of the design used for the line. It is recommended that the computations for preparing the package be filed with the permanent file copy of the package, together with a record of the lines constructed in accordance with the design. Such information may be valuable for future modifications or maintenance repair of the line.

B. CONTENTS OF THE STAKING DESIGN GUIDE

Following are recommendations concerning the material to be included in the package.

1. **General Information:**
   - Identification of the Design;
   - Date prepared;
   - Table of Contents.
2. **Design Criteria:**
   - The particular edition of the NESC used;
   - The particular local safety code in effect and used;
   - Utility standards or design guides used;
   - REA standard construction drawings used for basic structures;
   - Basic poles and other criteria selected for preparation of the staking guides;
   - Conductor sag-tension data used as a basis for conductor design.
3. **Staking Design Guides:**
   - Staking tables (for all design ruling spans used);
   - Pole strength tables;
   - Pin strength tables;
   - Angle limitations for various structure types;

- All applicable maximum span values;
- Tension limiting values for dead-ends, angles, etc;
- Guying guides;
- All other similar data prepared.

4. **Construction Guides:**
   - Conductor stringing tables;
   - Sagging method aids.

CHAPTER V-2
PREPARATION OF STRINGING SAG TABLES

A. PURPOSE OF STRINGING SAG TABLES

The primary purpose of stringing sag tables is to provide data needed to sag the conductor during the stringing operation. Initial sag tables are used for sagging new conductors. Final sag tables are used to resag used conductors which are assumed to have reached the final condition. The conductor which has previously been installed but not in place long enough to have reached final sag, may require special tables.

A secondary purpose of the tables is to provide additional information during the staking of the line. The tables are the best source of information available to the staker concerning the conductor sag under different conditions of temperature and span length. The final sags are usually most useful for this purpose.

Because of the dual use, the tables usually provide sag values through the complete range of spans which are anticipated in the line sections using the particular design. Thus the range of spans is usually longer than the desirable range for checking sag while sagging the conductor. It is suggested that the recommended range of spans for checking sag be identified by note or other means.

It is also suggested that the initial and final sag values be separated and that each table be identified with bold letters to flag the initial table and the final table.

B. BASIS OF THE TABLES

The tables are based on the unloaded initial and final design ruling span sag and tension values taken from the sag-tension data of the selected conductor design.

C. PREPARATION OF TABLES

The tables are usually prepared for temperature and span increments which are easy to interpolate in the field, e.g., increments of 5°C and 5 meters for metric tables and 10°F and 10 feet customary tables. The tensions used are the initial tensions for initial tables and final tensions for final tables.

Table V-1 is a condensation of a metric stringing sag table and is used as an aid in describing the preparation of a stringing sag table.

The first step in preparing a stringing sag table is to establish the column and row headings and values. The number of columns will be established by the number of tem-

TABLE V-1
DEVELOPMENT OF STRINGING SAG TABLE

Temperature °C	**0**	*5*	*10*	**15**	*20*	*25*	**30**
Initial Tension, N	**5237**	*4953*	*4668*	**4384**	*4109*	*3835*	**3560**
Span, Meters	Initial Stringing Sag, Meters						
80	0.33	0.35	0.36	0.38	0.42	0.45	0.48
90	0.41	0.44	0.46	0.49	0.53	0.57	0.61
100 R.S.	**0.51**	*0.54*	*0.57*	**0.60**	*0.65*	*0.70*	**0.75**
110	0.62	0.65	0.69	0.73	0.79	0.85	0.91
120	0.73	0.78	0.82	0.86	0.94	1.01	1.08

peratures for which it is desired to show sag and tension values and the number of rows will be set by the number of span lengths. The range of temperatures may vary with the local climate but as a minimum the range should be from the lowest to the highest temperatures for which it is probable that conductor will be strung and sagged. The range of span lengths should be, as a minimum, from the shortest to the longest span practical to use as a sag check span for the particular design ruling span. The condensed example table shows only five temperatures and five span lengths which is sufficient to demonstrate the procedure for preparing a table.

The next step is to enter into the table the sag, tension, and temperature values from the sag-tension data for the selected design ruling span. On Table V-1, these values are shown in bold type.

It will be common that the sag-tension data will not give sag and tension values for every temperature desired for the table. Therefore the next step is to interpolate and enter the missing design ruling span sag and tension values. For distribution line stringing sag tables, straight line interpolation will usually be adequate, therefore, the increments between the values given by the sag-tension data will be as nearly equal as permitted in rounding the interpolated values. On the example table the interpolated values are shown in italics. The row of sag values and row of tension values should at this point be complete for the design ruling span.

The next step is to fill in the sag values for the other span lengths for each condition of temperature. Taking one temperature at a time, the sag values are calculated using Equation V-2A. On the example table these values are shown in regular type.

$$D = D_r\left(\frac{S}{S_r}\right)^2 \qquad \text{EQ V-2A}$$

Where:
D = Calculated sag value
D_r = Design ruling span sag
S = Span length for which D is calculated
S_r = Design ruling span

The completed table should identify the conductor, design ruling span, design tension, and whether the table is for initial or final sags. Examples of complete stringing sag tables are provided in Appendix C.

CHAPTER V-3
STAKING TABLES

A. INTRODUCTION TO STAKING TABLES

The staking table design guide is probably the most useful design aid available to the line staker. The purpose, use, and application of the guide is discussed in Chapter VI-2 of this design manual. This chapter discusses the procedures for preparing a staking table.

The staking table can be relatively simple to prepare or may be very complex depending on configuration and separation of conductors at the structure supports, operating temperatures of the conductors, sag coordination between the conductors, maximum span lengths, and assumptions made in the preparation of the table.

The method for preparing staking guides which is described here will provide a table of the same accuracy as those which were historically prepared by the conductor manufacturers and were based on the requirements of 4th, 5th, and 6th editions of the NESC. The method used for preparing the table is far more complex than for the historic tables because of various rule changes introduced in the 1977 NESC.

The staking tables prepared as described in this chapter are used in the same way as the historic staking tables. The one difference is that the procedure described for preparation of the tables includes provision of design and construction tolerances for ground clearance and uplift factors. The historic tables left the application of tolerance entirely up to the judgement of the staker, consequently, the need for tolerances was often neglected.

B. GRAPHIC PRESENTATION OF CLEARANCE REQUIREMENTS

The NESC clearance requirements for conductors above ground were discussed in Chapter II-4 of Part II. A graphic representation of these

clearance requirements is shown in Figure V-1. The lines and parabolic curve shown on the figure represent final midspan sag clearances between ground and conductors operating at a temperature of 15°C [60°F] under various conditions described hereafter. The clearances are plotted as a function of conductor span length. The description of the clearance lines and curves are described below.

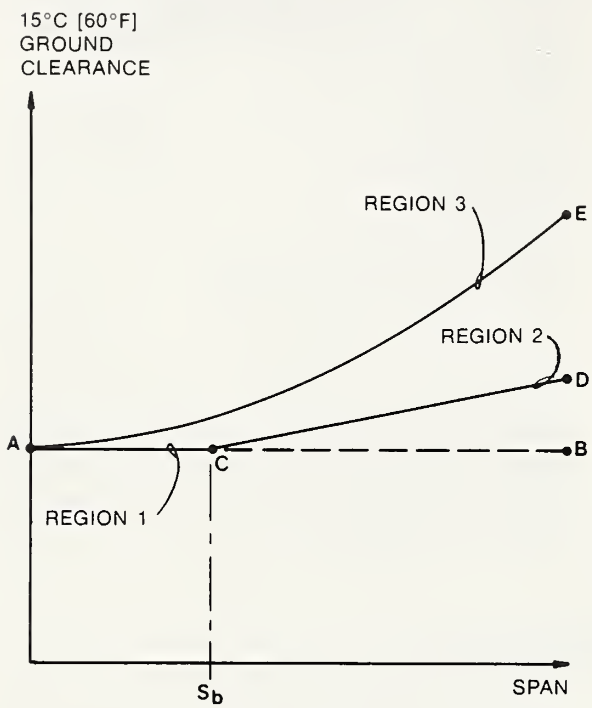


FIGURE V-1

- **Line AB**
  Line AB represents the basic line-to-ground clearance given in NESC Table 232-1.
- **Line AC**
  Line AC represents the minimum line-to-ground clearance up to the basic span length, S_b, for conductors operating at 15°C [60°F].
- **Line CD**
  Line CD represents the minimum line-to-ground clearance for span lengths greater than the basic span for conductors operating at 15°C [60°F]. Thus the vertical distance between CD and CB represents the incremental clearance increase for spans longer than the basic span.
- **Curve AE**
  Curve AE represents the 15°C [60°F] clearance of a conductor for which the maximum operating temperature is above 50°C [120°F]. The vertical distance between AE and AB represents the difference between the 15°C [60°F] final sag and the final sag of the conductor at the following condition, whichever difference is greater.

- 0°C [32°F] iced
- Maximum design operating temperature

In the following discussion, portions or segments of the lines or curves will be, for convenience, referred to as regions. The identification and description of each region are given by the following:

- **Region 1**
  Region 1 consists of the line segment AC.
- **Region 2**
  Region 2 consists of the line segment CD.
- **Region 3**
  Region 3 consists of the curve AE.

Regions 1 and 2 apply to supply lines which are designed to operate at or below a conductor temperature of 50°C [120°F]. Region 3 applies to supply lines which are designed to operate above 50°C [120°F].

NESC Rule 232B2c(3) discusses conditions which may result in clearance requirements less than those required by Region 2. However, for conductors and span lengths generally of interest in distribution line design, the relaxation of clearances which may be allowed by Rule 232Bc(3) is absent or negligible. Therefore, this rule has been ignored in the following discussions.

C. GRAPHIC REPRESENTATION OF STAKING TABLES

Figure V-2 is a graphic representation of the development of a typical staking table for a single controlling conductor. The 15°C [60°F] clearance requirements for the various span regions as shown by Figure V-1 are also included in Figure V-2.

A family of inverted parabolic curves representing conductor 15°C [60°F] midspan sags has been superimposed on the clearance requirements. The sag curves represent conductor clearances above ground for a series of rise values. One of the curves represents a level ground condition where the rise value is zero. The other curves represent midspan values of rise in increments of R_i both above and below level ground at midspan. The values below level

ground are depressions but are treated as negative rise values in the calculations.

At midpoint of any span length the height of the conductor above ground is defined by the following equation:

$H_y = H_c - R - D$

Where:

H_y = Conductor height at midspan
H_c = Conductor attachment height
R = Rise at midspan
D = Conductor sag at midspan

At midpoint of any span length the height of the clearance curve above ground is defined by the following equation:

$C_y = C_t + C_b + C_a$

Where:

C_y = Total clearance
C_b = Basic clearance required by NESC
C_t = Clearance design tolerance
C_a = Additional clearance required by NESC

The clearance available for sag, A_d, can be defined as:

$A_d = H_c - R - C_y$
$A_d = A_g - R$ EQ V-3A

Where:

$A_g = H_c - C_t - C_b - C_a$

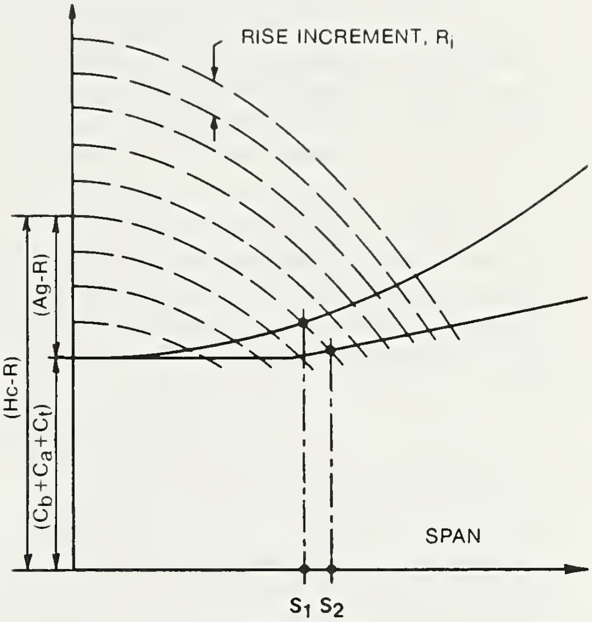
Where the sag curves intersect the clearance axis or where the span is equal to zero, the sag and the additional clearance, C_a, are also equal to zero, therefore, at the axis:

$H_y = H_c - R$
$C_y = C_t + C_b$
$A_g = H_c - C_t - C_b$

For any given rise condition, as the span length increases from zero, the conductor 15°C [60°F] final sag increases and the actual 15°C [60°F] clearance decreases. For maximum operating temperatures greater than 50°C [120°F], or span lengths greater than the basic span, the required clearance will be greater than the basic clearance. The intersection of the actual clearance curves with the required clearance curve determines the allowable spans for various rises or depressions.

As the rise increases the amount available for sag decreases; therefore, the allowable span length also decreases.

Given the same actual clearances, the following characteristics will be true.



S_1 = Allowable span for given rise condition where maximum operating temperature >50°C [120°F]
S_2 = Allowable span for given rise condition where maximum operating temperature ≤50°C [120°F]

FIGURE V-2

- The 15°C [60°F] actual clearance curve corresponding to the amount available for sag on level ground (R=0) intersects the required 15°C [60°F] clearance curve at a span defined as the level ground span.
- The allowable spans with maximum conductor operating temperatures in excess of 50°C [120°F] will be less than the allowable spans for maximum conductor operating temperatures equal to or less than 50°C [120°F].
- Data for different loading districts will result in different allowable spans since the basic spans will differ.
- An increase in basic span length will result in an increase in allowable span when the maximum conductor operating temperature equals or is less than 50°C [120°F].

D. COMPOSITE STAKING TABLES

Phase and neutral conductors will normally have different clearance requirements and at-

tachment heights. Consequently, the values of A_g under any given rise conditions will be different. Since the 15°C [60°F] sags may also differ, the actual clearances may change at different rates as the span length changes. As a result, the final staking table may be a composite table in which certain span regions are controlled by the clearance to the neutral conductor and other span regions are controlled by the clearance to the neutral conductor.

Figure V-3 exemplifies a case where both the phase and neutral conductors are operating at maximum temperatures less than or equal to 50°C [120°F]. For the example shown by Figure V-3, the following conditions occur.

- The amount available for sag for any given rise condition is greater for the phase conductor than for the neutral conductor.
- The phase conductor 15°C [60°F] sag is greater than the neutral conductor 15°C [60°F] sag. This means that as the span length increases the actual phase clearance reduces more rapidly than the actual neutral clearance.

Notice that for Rise Condition 1, the actual neutral 15°C [60°F] clearance curve intersects the required neutral 15°C [60°F] clearance line

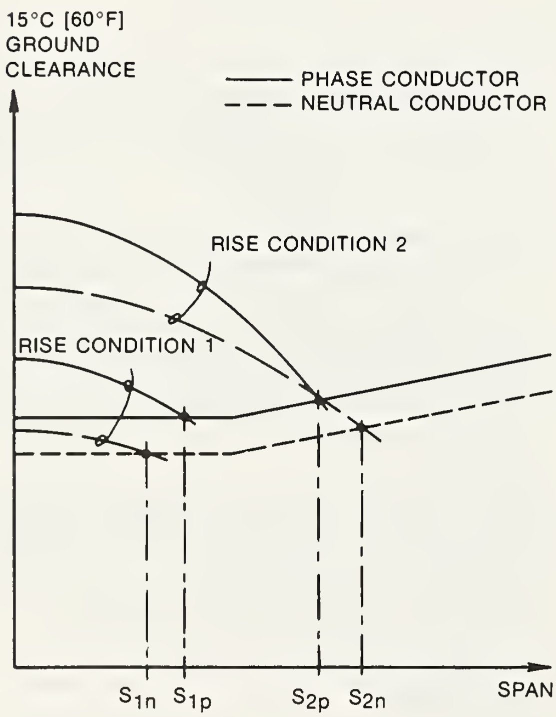


FIGURE V-3

at a shorter span length than for the phase conductor. Thus the neutral conductor clearance determines the allowable span.

For Rise Condition 2, the opposite is true. For this condition the actual neutral conductor 15°C [60°F] clearance curve intersects the required neutral 15°C [60°F] clearance line at a longer span length than for the phase conductor. Thus, the phase conductor clearance determines the allowable span.

E. STAKING TABLE CALCULATION METHOD

From the preceding discussion, it should be clear the analytical development of staking tables can be a complex procedure. The complexity is not due to the equations used in the calculations, which are relatively simple, but rather, to the number of tests and decisions which must be made in determining which equations to use. Because of the number of calculations and tests required, the preparation of a staking table is one that is best accomplished by use of a minicomputer or programmable calculator. The computation can be done manually, with the preparer performing the tests. Regardless of how the computation is performed, the procedure is most easily defined by the use of calculation flow diagrams.

A flow diagram is simply a graphic representation of the order of the computation procedure. Each block in the diagram contains a calculation procedure instruction. The use of a flow diagram is helpful when the procedure to be followed varies or branches depending on the results of certain calculation steps. At certain points in the procedure, the result or value of the preceding step is tested, and as a result of the test the continuation of the calculation procedure is directed to one of two alternate procedure methods.

F. DEFINITION OF SYMBOLS FOR FLOW CHART INSTRUCTION BLOCKS AND EQUATIONS

The symbols used in the instruction blocks of the flow charts and in the equations used for calculating the staking table data are as defined below.

D_r = Final conductor ruling span sag at 15°C [60°F]

D_{rn} = Final neutral conductor ruling span sag at 15°C [60°F]

D_{rp} = Final phase conductor ruling span sag at 15°C [60°F]
D_m = Final conductor ruling span sag at maximum operating temperature
D_{mp} = Final phase conductor ruling span sag at maximum operating temperature
D_{mn} = Neutral conductor ruling span sag at maximum operating temperature
D_u = Ruling span sag at minimum operating temperature
S_r = Ruling span length
S_a = Allowable span length
S_b = Basic span length as defined by NESC
S_c = Critical span length
S_{cb} = Longer of two values of S_c in Region 2
S_{cs} = Shorter of two values of S_c in Region 2
H_c = Conductor attachment height
H_{cp} = Phase conductor attachment height
H_{cn} = Neutral conductor attachment height
C_a = Additional clearance required by the NESC
C_b = Basic clearance given by NESC Table 232-1
C_{bp} = Basic clearance for phase conductor
C_{bn} = Basic clearance for neutral conductor
C_c = Total NESC code clearance
C_c = C_b+C_a
C_t = Ground clearance design tolerance
C_u = Uplift factor design tolerance
A_d = Available clearance for sag and rise
A_g = Available clearance for sag at midspan on level ground
A_g = H_c-C_t-C_c
A_g = H_c-C_t-C_b-C_a
A_{gp} = Available clearance for sag and rise for phase conductor
A_{gn} = Available clearance for sag and rise for neutral conductor
R = Rise above level ground at midspan (Depression is a negative rise)
R_i = Rise increment
R_1 = Upper rise limit for span calculations
R_2 = Lower rise limit for span calculations
R_m = Maximum rise above level ground at midspan, used as the first value of R_1 in span calculations
R_q = Rise above level ground at quarter span
T_m = Maximum operating temperature of conductor
T_{mp} = Maximum operating temperature of phase conductor
T_{mn} = Maximum operating temperature of neutral conductor
K = Calculation constant, as defined for specific equation

G. DESCRIPTION OF FLOW CHARTS

The flow diagrams used to guide the calculation procedures for preparation of the staking tables consist of the six flow charts shown by Figure V-4 through V-9. The first chart, Figure V-4, is a case selection chart and the remainder are case charts.

The instruction blocks contained in the diagrams are of two basic types which are distinguished by the shape of the block. Test blocks are diamond shape and calculation blocks are rectangular shape. The calculation blocks are subdivided into Critical Span Calculation Blocks, Rise Calculation Blocks, and Span Calculation Blocks. These are described in detail in the following sections. Each calculation block is provided with a step reference number at the upper left hand corner.

The data used in the computation procedure as directed by the instruction blocks, is taken from a Staking Table Data Sheet which is filled out before starting the calculations. A typical Staking Table Data Sheet form is shown by Table V-2 and an example of a data sheet which has been filled in is shown by Table V-3.

H. TEST BLOCKS

The diamond shaped Test Blocks are found in some of the flow diagrams. The primary purpose of the test blocks is to direct the flow of the computations. The instruction within the block asks a question concerning data taken from the data sheet or concerning a previous computation. The question is one that can be answered yes or no. If the answer is yes, follow the YES arrow out of the test block. If the answer is no, follow the NO arrow.

Some of the instructions ask that two values be compared, e.g., the value identified by the first symbol within the block is asked to be compared to the value of the second symbol. The following instructions are typical of the questions asked.

- $A>B$: Is the value of A greater than the value of B?
- $A<B$: Is the value of A less than the value of B?
- $A \leq B$: Is the value of A less than or equal to the value of B?
- Real Solution?: Is there a real solution to the value calculated?

The first three questions are self explanatory. The fourth question is discussed further in the next section.

I. CRITICAL SPAN CALCULATION BLOCKS

As the conductor span increases in length, it is probable that the clearance requirement which defines the required ground clearance will change. The change may be due to either a change in the region which defines the clearance requirement or in the conductor which controls the clearance. The span lengths where such changes occur are defined as critical span lengths, S_c.

The purpose of the Critical Span Calculation Block is to determine the span lengths at which such changes occur. The basic span length, (S_b), is a critical span length. However, the basic span is a fixed value defined by the NESC and is taken from the Staking Table Data Sheet. All other critical spans are variables and therefore must be determined.

The Critical Span Calculation Block contains an instruction similar to the following example.

SOLVE EQ H
FOR S_c

This example is an instruction to solve for the critical span length using Equation H as found hereafter in the text.

The Test Block which follows the calculation block provides an appropriate instruction for evaluating the resulting value for S_c, and indicates the direction to be followed in the flow chart for the continuation of the calculation procedure.

Certain of the equations used to determine the value of S_c involve taking the square root of a mathematical expression. If the expression under the radical sign is negative, there will be no real solution for S_c. The test for this possibility is one of the tests that may be encountered in the flow chart. Thus, if the Test Block asks if there is a real solution and there is none, follow the direction of the NO arrow. If the expression under the radical sign is positive, the square root of the value consists of two numbers of equal value but one positive and the other negative. Thus, there will be two answers for the value of S_c. With one exception, only the result which includes the positive root should be used for S_c. However, for Equation I, both the positive and negative root values are retained and the results are identified as S_{cb} and S_{cs}; where S_{cb} is the longer and S_{cs} the shorter of the two values. Since these are real solutions, continue the calculation procedure by following the YES arrow.

Once the critical span values have been determined and tested, they should be recorded on the Staking Table Computation Sheet.

J. RISE CALCULATION BLOCKS

The purpose of the Rise Calculation Block is to determine the midspan ground rise value which will just allow a particular critical span length. The Rise Calculation Block will contain an instruction similar to the following example.

RISE
S_b
NEUT
EQ C

The word RISE appears on the first line and identifies the block as a Rise Calculation Block.

The second line identifies the critical span length value to be used to calculate the allowable rise. Therefore, in the above example block, the basic span length, S_b, is used for the calculation. Other critical span values which may appear in the block include S_c, S_{cb}, and S_{cs}. If instructed to use any of the latter three critical span values, use the value previously calculated and recorded in the Staking Table Computation Sheet.

The third line of the example indicates which conductor data to use in the equation. The data for the phase or neutral conductor is taken from the Staking Table Data Sheet. If only three lines appear in the rise block, it will be this line which will be missing. If not included, the conductor data to be used will have been identified by the Case Selection Chart.

The last line within the Rise Calculation Block indicates which equation to use for

calculating the midspan ground rise value which will just allow a particular critical span length. The example indicates that Equation C found hereafter in the text is to be used. The value calculated is used as a limiting value of rise for calculating a range of allowable spans. For the staking table it is desired that all allowable spans be functions of regular increments of rise values. Therefore, the calculated value is rounded to a multiple of the incremental rise value, R_i. For use with the flow charts included herewith, the calculated value should be rounded up to next larger multiple of R_i.

If the rise value calculated is a negative number it is an indication that the value represents a depression below level ground. In the calculations depressions are treated as negative rises. When rounding a depression value the rounding should be in the positive direction.

K. SPAN CALCULATION BLOCKS

Following each Rise Calculation Block, a Span Calculation Block is encountered in the flow diagram. Each Span Calculation Block includes the instructions for performing a series of allowable span calculations, therefore, the majority of the calculations performed in preparing a staking table will result from the instructions contained within this type of calculation block. Each Span Calculation Block will include instructions similar to the following example.

SPANS
R_1=Rm
R_2=STEP 2
NEUT
EQ B

The word SPANS appears on the first line and identifies the block as a Span Calculation Block.

The second and third lines are instructions which assign values to the terms identified as R_1 and R_2 respectively. The values assigned to these terms identify the limits to the range of rise values for which the series of spans are to be calculated. R_1 identifies the upper limit rise value and R_2 the lower limit rise value for the range of rise values.

The third line of the example indicates that data for the neutral conductor is to be used in the calculations. Either NEUT or PHASE may appear at this location, except that in Case 1, this instruction is missing and the conductor data to be used will have been identified by the Case Selection Chart.

The last line of the instruction indicates which equation to use in the calculations.

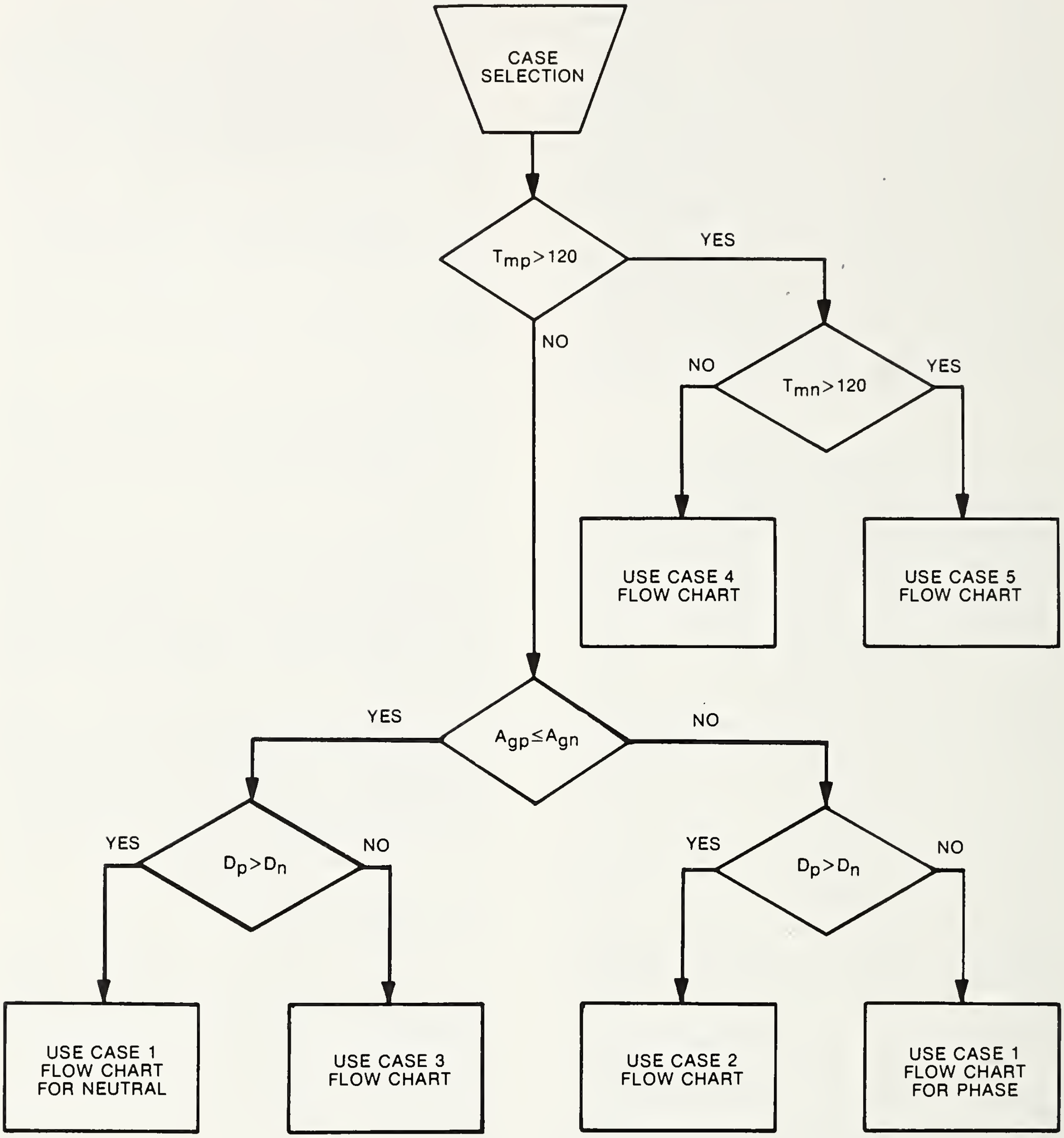
The first value which will be assigned to R_1 in any flow chart will be R_m. This is the maximum rise value for which the table is to be prepared and results in the shortest allowable span value. The first value assigned to R_2 is the rise corresponding to the shortest critical span value. The instruction in the above example indicates that R_2 is to be assigned the rise value previously calculated in Block 2 step of the flow chart. If there is no critical span value identified, then R_2 is set equal to MIN. DESIRED. The meaning of this value is explained hereafter.

The Span Calculation Block thus defines the criteria for a series of span calculations for incremental steps of rise values from R_1 down to R_2. The first span calculation for the block uses the value of R_1 in place of R in the equation specified by the last line of the block. The second calculation uses $(R_1\text{-}R_i)$ in place of R, where R_i is the incremental change in rise value. Allowable spans continue to be calculated for values of R, with R decremented after each calculation, until R reaches the value assigned to R_2.

After each span calculation, Equations L and M are used to calculate the associated values for the allowable quarter span rise and for the uplift factor for the calculated span value. This instruction is automatic and is not included in the flow chart instructions. The calculated values for each span are recorded on the Staking Table Computation Sheet.

When the value of R reaches the value assigned to R_2, a critical span length will have been reached. This signifies that a change needs to be made in the span calculation procedure. The change may be the replacement of the conductor data, a change in the equation to be used, or both. The range limits for R also need to be replaced. The new value for the upper limit R_1 is set equal to the R_2 limit of the preceding range less one incremental step R_i.

If the R_2 lower limit for the new range will be set by another critical span length, the flow diagram is directed to another Rise Calculation Block to determine the new R_2 limit value, and then proceeds on to a new Span Calculation Block.



CASE SELECTION FLOW CHART

FIGURE V-4

For those conditions where there are no additional critical span lengths, there will be no new lower limit value for R_2. The flow diagram, therefore, proceeds directly to a new Span Calculation Block. The instruction for R_2 in this block will indicate R_2=MIN. DESIRED. This indicates that the allowable span calculations should continue until a span value is reached which equals the maximum value desired for the staking table. At this span length the rise value will be at the minimum desired value.

The maximum span value desired for the staking table may be reached in any one of the span calculation blocks of the flow diagram. When this value is reached, the span calculations may be terminated.

L. CASE SELECTION FLOW CHART

Five separate flow chart cases are required to cover the several combinations of controlling conditions which determine the allowable spans as a function of midspan ground rise. The Case Selection Flow Chart is used to analyse these conditions and to select the proper case to be used for the computation.

Prior to the start of the calculation, the Staking Table Data Sheet is filled in. In the first step of the calculation procedure, the Case Selection Flow Chart is used to test selected items of the data. Questions are asked by the Test Blocks of the Case Selection Flow Chart which, when properly answered, will direct the user to the proper case flow chart.

M. FLOW CHART CASES

Following are given the conditions upon which each of the five flow chart cases are based. In applying the flow chart cases, the data is taken from the previously prepared Staking Table Data Sheet. The results of the calculations are recorded on the Staking Table Computation Sheet. The computation sheet is prepared in a manner similar to the example shown by Table V-4.

- **Case 1**

The line-to-ground clearances to only one conductor control throughout the entire staking table. Figure V-5 shows the flow chart for Case 1.

- **Case 2**

The controlling clearance changes from the neutral conductor, to the phase conductor as the spans increase. Figure V-6 shows the flow chart for Case 2.

- **Case 3**

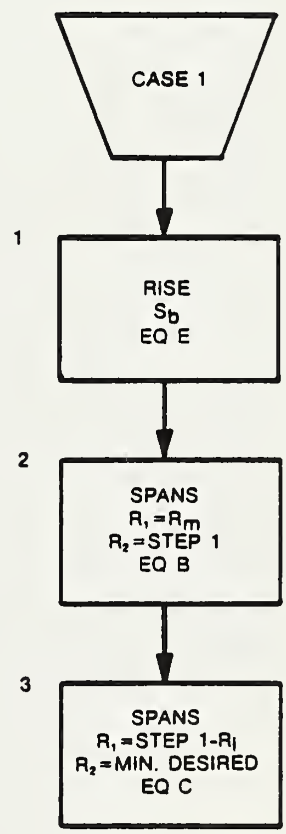
The controlling clearance changes from the phase conductor, to the neutral conductor as the spans increase. Figure V-7 shows the flow chart for Case 3.

- **Case 4**

The maximum operating temperature of the phase conductor is greater than 50°C [120°F], but the maximum operating temperature of the neutral conductor is equal to or less than 50°C [120°F]. Figure V-8 shows the flow chart for Case 4.

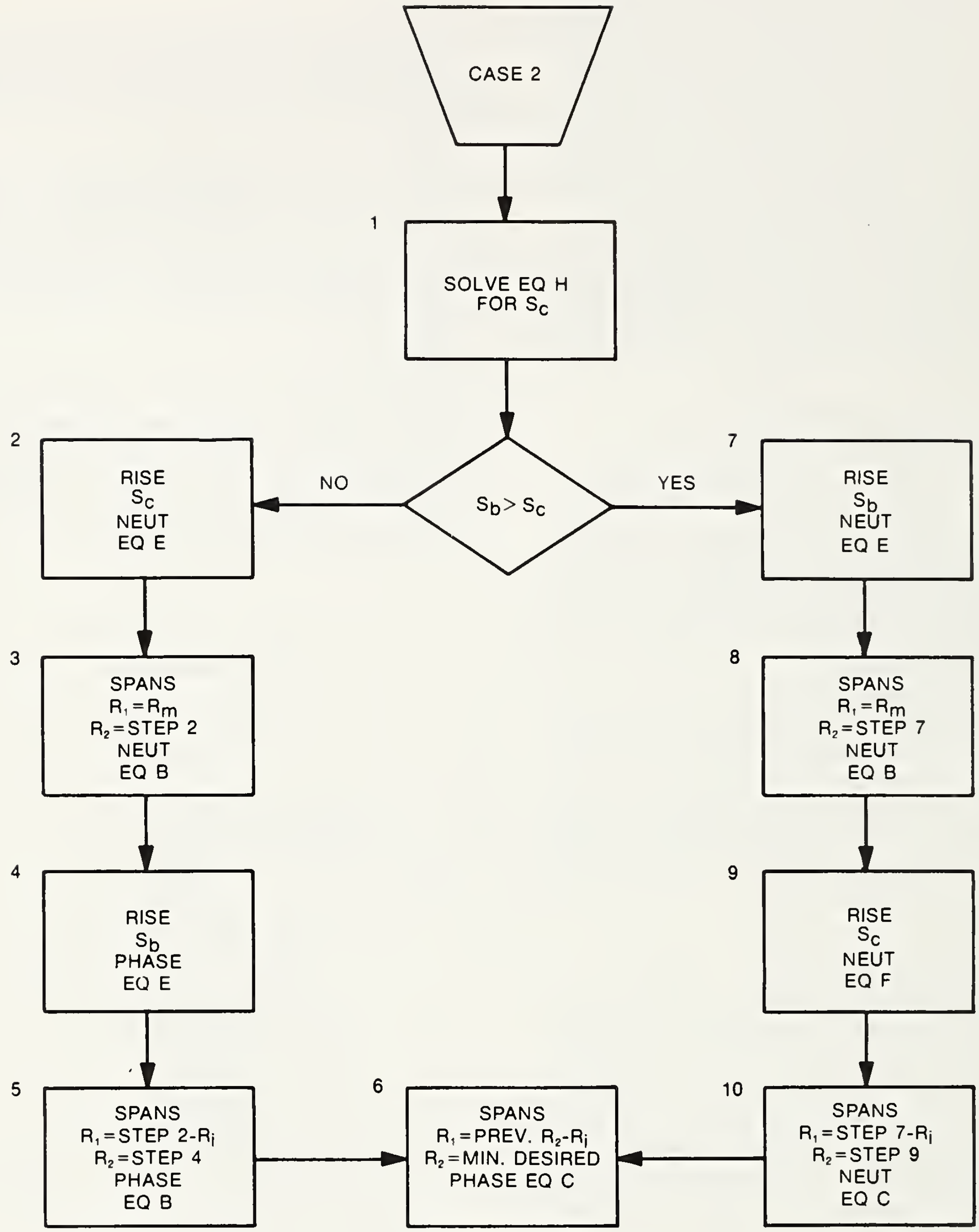
- **Case 5**

The maximum operating temperatures of both the phase and neutral conductors are greater than 50°C [120°F]. Figure V-9 shows the flow chart for Case 5. This case is applicable only in areas where the ambient air temperature occasionally exceeds 50°C [120°F].



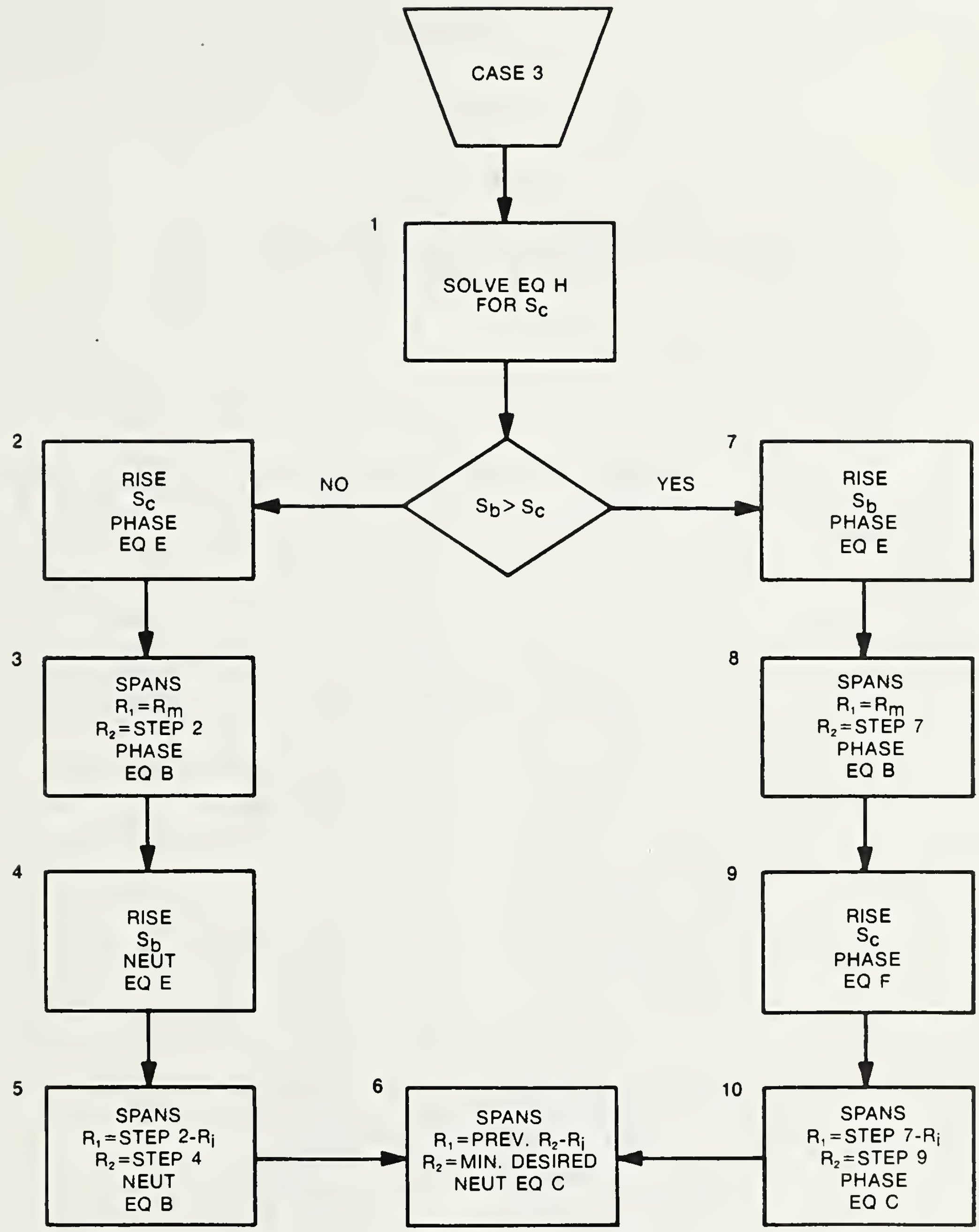
CASE 1 FLOW CHART

FIGURE V-5



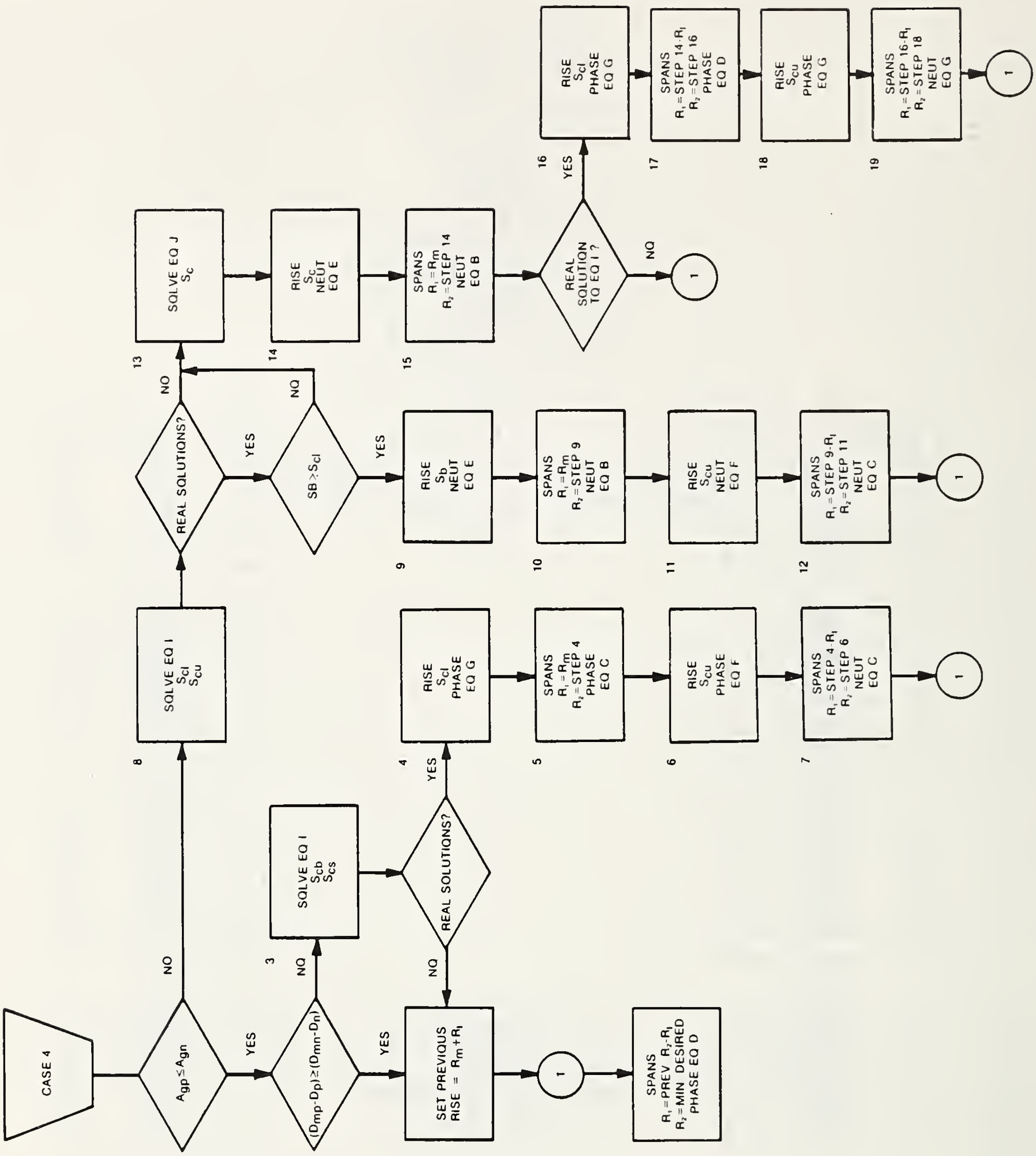
CASE 2 FLOW CHART

FIGURE V-6



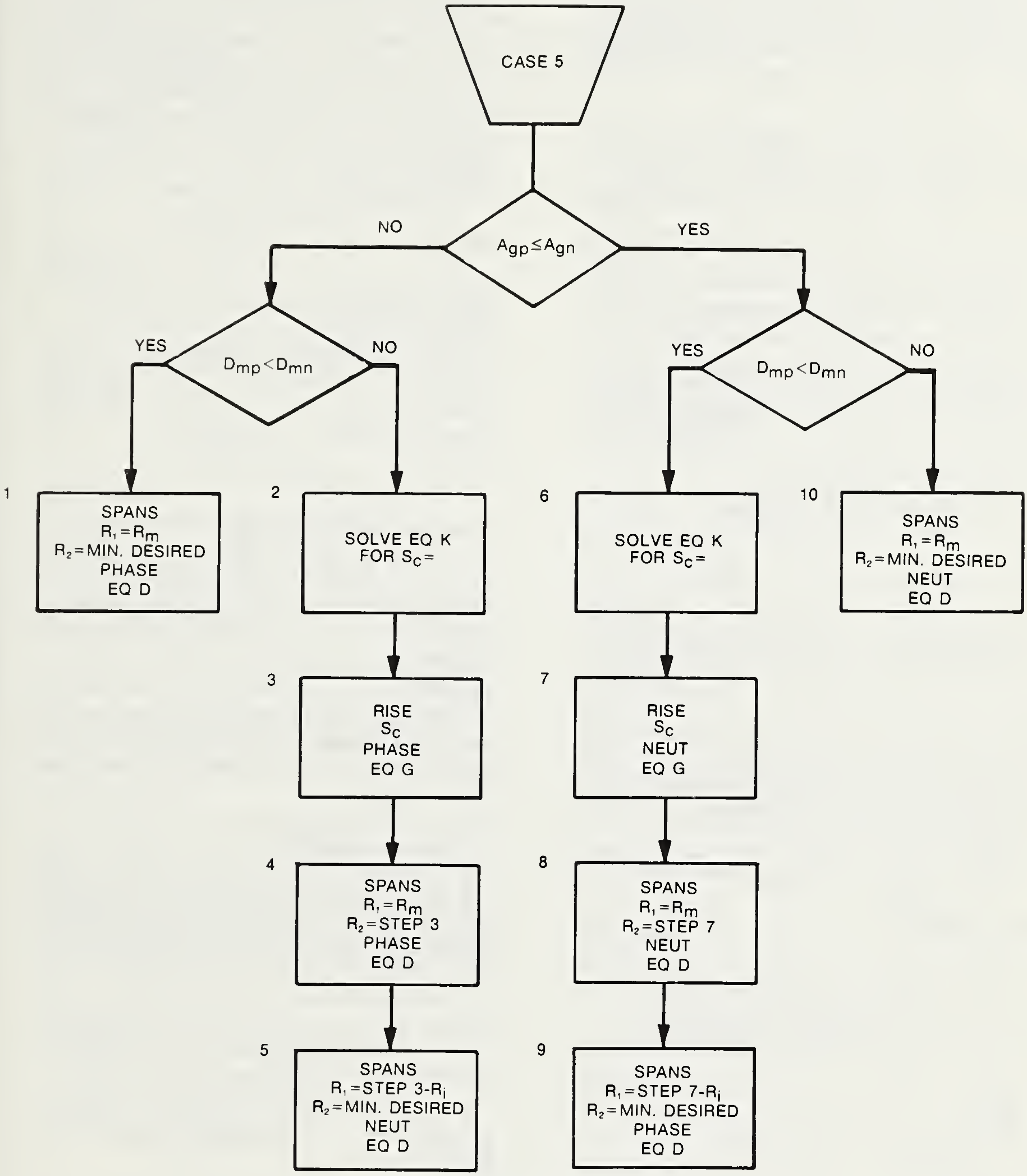
CASE 3 FLOW CHART

FIGURE V-7



CASE 4 FLOW CHART

FIGURE V-8



CASE 5 FLOW CHART

FIGURE V-9

N. FLOW CHART EQUATIONS

The following equations are referenced at various points within the flow charts. The parameters used in these equations are defined either by the Staking Table Data Sheet or as they are used in the flow charts.

Not all of the terms appearing in the equations given thereafter are fully subscripted. In some cases the full subscript will depend on which conductor data is to be used. For example, the Equation E, given hereafter, the value used for D_r may be the value D_{rp} or the value D_{rn} depending whether the flow chart has instructed to use the phase conductor ruling span sag data or the neutral conductor data.

Note that the equation identifications as referenced in the text and on the flow charts are abbreviations of the design manual equation reference identifications, e.g., EQ B is used to identify equation EQ V-3B.

1. Span Calculation Equations

The span calculation equations are used to determine the maximum allowable span for a given condition of rise or depression. In the equations a depression is treated as a negative rise. The basis for the equations is simply the substitution of the clearance available for sag (A_g-R) for the sag value in the basic sag equation. All values except R are taken from the Staking Table Data Sheet. R is varied in regular increments R_i, from the upper rise limit R_1 to the lower limit R_2, and the corresponding value of allowable span, S_a; is calculated.

- **EQ B**
  Span calculation for spans in Region 1

$$S_a = S_r\sqrt{\frac{A_g-R}{D_r}} \qquad \text{EQ V-3B}$$

- **EQ C**
  Span calculation for spans in Region 2

$$S_a = (-K)+\sqrt{\frac{K^2+4K[(S_b)+(100)(A_g-R)]}{2}} \qquad \text{EQ V-3C}$$

Where:

$$K = \frac{S_r^2}{100\ D_r}$$

- **EQ D**
  Span calculation for spans in Region 3

$$S_a = S_r\sqrt{\frac{A_g-R}{D_m}} \qquad \text{EQ V-3D}$$

2. Rise Calculation Equations

The rise calculation equations are used to determine the permissible value of rise relative to level ground at a previously calculated critical span value, S_c. All other values are taken from the Staking Table Data Sheet. The calculated values are rounded as discussed in Section J.

- **EQ E**
  Rises in Region 1

$$R = A_g - D_r\left(\frac{S_c}{S_r}\right)^2 \qquad \text{EQ V-3E}$$

- **EQ F**
  Rises in Region 2

$$R = A_g - D_r\left(\frac{S_c}{S_r}\right)^2 - [0.01(S_c-S_b)] \qquad \text{EQ V-3F}$$

- **EQ G**
  Rises in Region 3

$$R = A_g - D_m\left(\frac{S_c}{S_r}\right)^2 \qquad \text{EQ V-3G}$$

3. Critical Span Equations

The critical span equations are used to calculate the value of the spans at which the control changes from one conductor to another or where the region controlling the clearance changes.

- **EQ H**
  This equation is used for the calculation of the span at which the control changes from one conductor to the other for $T_m \leq 50°C$ [120°F] for both conductors

$$S_c = (S_r)\left(\frac{A_{gp}-A_{gn}}{D_p-D_n}\right)^{1/2} \qquad \text{EQ V-3H}$$

If the value within the radical is positive and $D_n > D_p$, then the phase conductor clearance controls for spans below S_c, and the neutral conductor clearance controls spans above S_c.

If the value within the radical is positive and $D_n < D_p$, then the neutral conductor clearance controls spans below S_c, and the phase conductor clearance controls spans above S_c.

If the value within the radical is negative, clearance to only one conductor controls for all spans.

- **EQ I**
  Calculation for the range of spans lengths in Region 2 where the neutral conductor will control. This equation is used in the Case 4 flow chart only.

$$S_c = \frac{K \pm \sqrt{K^2 - 4K[S_b - 100(A_{gp} - A_{gn})]}}{2} \qquad \text{EQ V-3I}$$

Where:

$$K = \frac{S_r^2}{100(D_{mp} - D_n)}$$

- **EQ J**

Calculation for the upper span in Region 1 where the neutral conductor will control. This equation is used in the Case 4 flow chart only.

$$S_c = (S_r)\left(\frac{A_{gp} - A_{gn}}{D_{mp} - D_n}\right)^{1/2} \qquad \text{EQ V-3J}$$

- **EQ K**

Calculation for the span at which the control changes from one conductor to the other when the conductor operating temperature is greater than 50°C [120°F] for both conductors. This equation is used in the Case 5 flow chart only.

$$S_c = (S_r)\left(\frac{A_{gp} - A_{gn}}{D_{mp} - D_{mn}}\right)^{1/2} \qquad \text{EQ V-3K}$$

4. **Quarter Span Rise Calculations**

- **EQ L**

Calculation for quarter span rise.

$$R_q = \frac{D_r}{4}\left(\frac{S_a}{S_r}\right)^2 + R \qquad \text{EQ V-3L}$$

EQ L is somewhat conservative in that it does not take into account the fact that any clearance adders to the basic clearance are a function of the location in the span. The clearance adder at quarter span is only 75 percent of the midspan clearance adder.

The omission of this small correction simplifies the calculation and results in conservative quarter span rises. It is suggested this correction be included in any computation performed in a computer program. The method for calculating these corrections is discussed in Section J of Part II.

5. **Uplift Factor Calculations**

- **EQ M**

Calculations for uplift factor.

$$F_u = 4\,D_u\left(\frac{S_a}{S_r}\right)^2 - C_u \qquad \text{EQ V-3M}$$

O. PREPARATION OF THE STAKING TABLE

The preparation of the staking table will generally proceed in the following manner.

Step 1

Fill out the Staking Table Data Sheet. Table V-2 shows a typical data sheet. Table V-3 shows a data sheet which has been filled in for an example problem.

Step 2

Use the Case Selection Flow Chart to determine which case flow chart to use for the calculations.

Step 3

Using the designated Case Flow Chart perform the computations as directed by the instructions included in the flow diagram. Record the results of the computations on a Staking Table Computation Sheet. Table V-4 shows an example of a typical computation for a simple Case 1 problem.

Key results are tabulated at the bottom of Table V-4 as they are determined. This is done in order to facilitate the checking of the computations.

Step 4

Continue the calculations until data is obtained for the desired range of span lengths or rise values.

Step 5

Using the Staking Table Computation Sheet prepare the staking table using a form of presentation easily used during staking. Table VI-3 of Chapter VI-2 is an example of such a form. Other examples are included in Appendix C.

The equations used and the results of the computations performed while progressing through the flow chart are tabulated in a manner similar to that shown on Table V-4.

The table can be expanded to include additional pole heights without having to calculate new allowable spans. All that needs to be done is to add $(H_1 - H_2)$ to each of the center span rises. H_1 is the pole height above ground for the pole on which the table is based. H_2 is the new pole height. New quarter span rises also need to be calculated for the new combinations of span and center span rises.

Table VI-3 of Chapter VI-2 is an example of one manner in which the final table can be presented.

TABLE V-2
STAKING TABLE DATA SHEET

Loading District:	______
Pole Height:	______
Basic Span, S_b:	______
Basic Desired Range of Span Lengths:	______
Maximum Rise, R_m:	______
Staking Table Midspan Rise Increment, R_i:	______
Staking and Construction Tolerance, C_t:	______
Ruling Span, S_r:	______
Cold Initial S_r Sag, D_u:	______
Uplift Tolerance, C_u:	______

Conductor Information:	Phase	Neutral
(1) Maximum Operating Temp., T_m	T_{mp} = ______	T_{mn} = ______
(2) Attachment Ht., H_c	H_{cp} = ______	H_{cn} = ______
(3) Basic Clearance, C_b	C_{bp} = ______	C_{bn} = ______
(4) Amount Available for Sag on Level Ground, $A_g = H_c - C_b - C_t$*	A_{gp} = ______	A_{gn} = ______
(5) 15°C [60°F] Final S_r Sag, D_r	D_{rp} = ______	D_{rn} = ______
(6) Greater of Either Final T_m S_r Sag or 0°C [32°F] Iced S_r Sag, D_m	D_{mp} = ______	D_{mn} = ______

* Do not include C_a. In Region 1, $C_a = 0$. In Region 2 and Region 3, C_a is calculated as part of the equation.

TABLE V-3
STAKING TABLE DATA SHEET
(Example)

Loading District:	NESC Heavy loading	
Pole Height:	11 m	
Basic Span, S_b:	53.3 m	
Basic Desired Range of Span Lengths:	50 — 200 m	
Maximum Rise, R_m:	1.6 m	
Staking Table Midspan Rise Increment, R_i:	0.2 m	
Staking and Construction Tolerance, C_t:	0.2 m	
Ruling Span, S_r:	100.0 m	
Cold Initial S_r Sag, D_u:	0.38 m	
Uplift Tolerance, C_u:	0.0	
Conductor Information:	Phase	Neutral
(1) Maximum Operating Temp., T_m	T_{mp} = 50	T_{mn} = 50
(2) Attachment Ht., H_c	H_{cp} = 9.2	H_{cn} = 7.85
(3) Basic Clearance, C_b	C_{bp} = 6.1	C_{bn} = 5.5
(4) Amount Available for Sag on Level Ground, $A_g = H_c - C_b - C_t$*	A_{gp} = 2.9	A_{gn} = 2.15
(5) 15°C [60°F] Final S_r Sag, D_r	D_{rp} = .98	D_{rn} = 1.12
(6) Greater of Either Final T_m S_r Sag or 0°C [32°F] Iced S_r Sag, D_m	D_{mp} = 1.54	D_{mn} = 1.49

* Do not include C_a. In Region 1, $C_a = 0$.
In Region 2 and Region 3, C_a is calculated as part of the equation.

TABLE V-4
TYPICAL STAKING TABLE COMPUTATION SHEET

Case Flow Chart: 1

Step	Eq.	Condr.	Rise	Span	1/4 Span Rise	Fu
1	E	N	2.0			
2 Skipped Because R_m <2.0 in						
3	C	N	1.6	63	1.8	.6
3	C	N	1.4	71	1.7	.8
3	C	N	1.2	79	1.5	.9
			•			
			•			
			•			
3	C	N	0.0	116	0.7	2.1
			•			
			•			
			•			
3	C	N	-4.0	204	-1.8	6.3
3	C	N	-4.2	207	-1.9	6.5
3	C	N	-4.4	211	-2.0	6.8

KEY RESULTS

Critical Spans		Rise Ranges		
Critical Span	Allowable Rise At Critical Span	Block No.	R_1	R_2
53.3 m	2.0 m	2	R_m = 1.6 m	2.0 m
		3	1.6	-4.4

(1) The first R_1 value will equal R_m. If R_2 is greater than R_m, the span calculation block is skipped. In the next span calculation block R_1 should be assigned the value of R_m.

CHAPTER V-4
POLE STRENGTH CALCULATIONS AND GUIDES

A. INTRODUCTION TO POLE STRENGTH CALCULATIONS

This chapter describes the procedures for calculating the strengths of unguyed pole structures and the preparation of the pole strength staking guides. The general application of pole strength guides used in the staking of a line is discussed in Part VI - Staking the Overhead Distribution Line.

This chapter is limited to the discussion of single based poles acting as simple cantilever beams. Unguyed structures used on primary circuits of rural lines are essentially limited to use as tangent structures and small angles. Such structures do support the vertical weight of the attached conductors but these loads are seldom a factor in determining the strength of the pole.

Pole Strength Tables or Maximum Span Tables tabulate the maximum allowable spans permitted for a series of pole heights and classes for a given species, specific pole top assembly, and number of conductors of specified size and type. They may also provide an adjustment factor for small angles.

The pole strength tables are based on the maximum horizontal span or wind span which is defined as the sum of one half of the adjacent span in each direction from the pole structure. The tables may present the allowable span either as the allowable horizontal span or as the allowable sum-of-adjacent spans. The table should indicate which presentation is being used. The preferred presentation is the choice of the user. In the first case the user calculates the average of the two spans. In the second case the user calculates the sum of the two spans when applying the tables.

Poles used in guyed structures are considered struts with only the vertical loads applied; however, the strength of the structure above the guy attachment is calculated in the same manner as an unguyed pole and is discussed in this chapter. The column strength of a pole, acting as a strut, is discussed in Chapter V-6.

B. STRENGTH AND DIMENSIONS OF WOOD POLES

The NESC indicates that the designated fiber stress, material, and dimensions of natural wood poles, should conform to ANSI 05.1 Specifications and Dimensions for Wood Poles. The 1981 NESC references ANSI 05.1-1979. For systems of REA Borrowers, the poles should also conform with the current REA Specification DT-5C, "Wood Poles, Stubs, and Anchor Logs and Preservation Treatment of these Materials." This specification also references ANSI 05.1.

ANSI 05.1-1979 classifies poles by wood species, length and strength class. The minimum circumference six feet from the butt of each class pole is calculated such that a specified load applied horizontally at a distance of two feet from the top will not exceed the designated modulus of rupture of the pole at the ground line. Thus, all poles of a given class will withstand approximately the same load, regardless of the height or species. For a given pole class and height, the ground line circumference for different species, will differ because of differences in allowable fiber stress.

It is common practice to abbreviate pole classifications, e.g., a pole identified as 35-6, implies a pole, 35 feet in length with a strength classification of 6 as defined by ANSI 05.1. ANSI 05.1-1979 defines a Class 6 pole as one which will hold a 1500-pound load applied 2 feet from the top of the pole.

It is contemplated that future editions of ANSI 05.1 will be metric and will be based on a new classification system. Therefore, it is probable that the future metric values will be other than a simple hard conversion. For example, should the currently proposed metric classification system be adopted, the closest equivalent to the common 35-6 pole would be an 11 m (36.1 ft), Class M9 pole, with a setting depth of 1.8 m (5.9 ft). The pole would hold a load of 6900 N (1551 lb) applied 60 cm (23.6 in) from the top. Thus a soft metric conversion of the strength and wind loadings for a customary 35-6 pole would not be compatible with the values for a metric 11-M9 pole. The reader is cautioned that this example is based on a tentative proposed classification system which may or may not be adopted.

Because of the number of values which are involved in pole strength computations and to

avoid future confusion as to which classification system was used for computations, the following computation procedure is recommended.

- Pole strength computations based on customary versions of ANSI 05.1 should be performed using customary units. Convert the results to metric units if the design data is to be presented in metric units.
- Pole strength computations based on metric versions of ANSI 05.1 should be performed using metric units. Convert the results to customary units if the design data is presented in customary units.

Equations for both methods of computation are presented hereafter. Example computations are based on the 1979 edition of ANSI 05.1.

C. SOURCES OF POLE DATA

Pole dimensions and strength data are available from the following sources:

- **ANSI 05.1.** For distribution pole sizes the customary values given in the 1972 and 1979 editions are the same. Data based on either edition is suitable for use with the 1981 NESC.
- **REA Specification DT-5C.** 1982 edition values are based on ANSI 05.1-1979 and are valid to use with the 1981 NESC.
- **REA Staff Report - "Dimensions and Resisting Moments of Wood Poles,"** The edition reprinted 1976 is based on the 1972 ANSI 05.1. This report provides pole data and partial results for some pole strength computations.

D. STRENGTH REQUIREMENTS OF POLE STRUCTURES

The basis for design of wood pole structures is established by the NESC. The basic strength requirements and structure loading were discussed in Chapter IV-11. It was indicated that the design loads supported by the structure are multiplied by overload capacity factors to derive the values of force used to calculate the required strength of the structure.

When the design loads are known, the required ground line resisting moment of the pole is calculated using these derived forces. The required resisting moment is then compared to the actual resisting moment of the different classes of poles. The class pole is selected which just meets or exceeds the required moment. The principal steps of this method include the following:

- Determine the longitudinal, transverse, and vertical loads of each attached conductor span.
- If the design load vectors are not in the same direction as the three-dimensional coordinates used for the design of the structure, resolve the load vectors into components based on the structure design coordinates. This step is usually needed for angle structures but not for tangent structures.
- Select the appropriate design overload capacity factor for each load. Multiply each load vector by the proper factors to derive the values of force used to determine the required strength.
- Multiply each force acting in the transverse direction by the distance from the ground line to the height at which the force is applied to obtain the transverse force moment.
- Calculate the summation of all transverse force moments, including the wind moment on the pole. This summation of moments is the required resisting moment of the pole.
- Determine the smallest class pole for which the resisting moment will equal or exceed the required resisting moment.

The moments in the direction of the longitudinal coordinate usually do not need to be calculated. These vectors oppose each other and essentially cancel out unless there is a change in horizontal conductor tension at the structure. The vertical loads must also be supported by the pole, however for tangent and small angle unguyed poles this is very seldom a factor in determining pole class.

When it is desired to know the maximum span permitted for a particular pole class, the procedure given above is reversed. The maximum design load permitted by a particular class pole is calculated. The design load is resolved to find the maximum allowable span. This is the procedure used in preparing a pole strength table. The equations are given and procedure demonstrated in later sections of this chapter.

E. OVERLOAD CAPACITY FACTORS

The application of overload capacity factors was discussed in Chapter IV-11. NESC overload

capacity factors for wood pole structures are given in NESC Table 261-3 and also in Table II-12 found in Chapter II-11 of this design manual.

As discussed in Chapter IV-11, the NESC overload capacity factors are generally used as the design overload capacity factors. Increased factors are used in those cases where increased reliability is needed.

F. DESIGN LOADS

The source of the design loads is discussed in Chapter IV-11. The loads are based on the conductor loading and sag-tension data for the design ruling span. On occasion, a basic structure design tension value is selected which differs from the design ruling span tension. When such a value is given as basic design criteria, this value should be used in the computations.

G. DIRECTION OF CRITICAL LOADING

In designing a supporting structure, there is a direction of loading which is most critical in determining the required strength of the structure. When this direction is known, computations for strength requirements need be made only for this direction of loading.

If there is no change in the longitudinal tension of the conductor, the critical direction for the tangent and small angle wood pole structures is in the transverse direction.

For the tangent structures, the transverse coordinate of the structure is perpendicular to the line. For small angle structures the transverse coordinate of the structure is in the direction of the bisector of the angle.

H. EQUATIONS FOR LOADING MOMENTS

The total ground line moment, M_g, which the pole resists equals the sum of all force moments applied to the pole due to wind loads on the conductors and pole plus any tension loads imposed by the conductors due to a line angle.

$$M_g = S_h M_c + M_t + M_p \qquad \text{EQ V-4A}$$

Where:

S_h = Horizontal wind span (1/2 the sum of adjacent spans), m (ft)

M_c = Summation of moment loads due to wind on each conductor expressed as moment per unit length of span, N•m/m (lb•ft/ft)

M_t = Summation of moments due to the tension in each conductor, if there is a line angle, N•m (lb•ft)

M_p = The moment due to wind on the structure

$$M_c = F_{ow}[\Sigma(W_c H_c)]\cos(\theta/2) \qquad \text{EQ V-4B}$$

$$M_t = 2F_{ot}[\Sigma(T_c H_c)]\sin(\theta/2) \qquad \text{EQ V-4C}$$

$$M_p = F_{ow} W_p \left(\frac{2C_t + C_g}{K_c}\right) H_p^2 \qquad \text{EQ V-4D}$$

Where:

F_{ow} = NESC ocf for wind loads (See Chapter II-11)

F_{ot} = NESC ocf for tension loads

H_p = Height of pole above ground, m (ft)

H_c = Height of each conductor attachment, m (ft)

W_c = Wind load per unit length of each conductor, N/m (lb/ft)

W_p = Wind load per unit area surface of pole, Pa (lb/ft²)

T_c = Tension in each conductor, N (lb)

0 = Line angle at pole

C_t = Pole circumference at top, mm (in)

C_g = Circumference at ground line, mm (in)

K_c = Calculation constant

K_c = 6000π, metric computations, circumference in millimeters

K_c = 72π, customary computation, circumference in inches

When the line angle θ is zero, the cosine is one, and the sine is zero, in which case M_t drops out of the equation.

When the structure supports equipment of sufficient cross-section to have appreciable impact on the wind load moment, this should be calculated and added to the moment due to wind on the pole, M_p.

I. CALCULATION OF MAXIMUM HORIZONTAL SPAN

For most pole strength calculations, what is desired is the maximum permissible span for a given pole species, height, and class. When the species to be used has not been determined, base the calculation on the probable species which will have the most restrictive wind moment load on the poie. This is the species with the lowest allowable fiber stress.

The resisting moment of the pole at ground line, M_r, must equal or exceed the total ground line moment, M_g, due to the applied loads.

It should be noted that the circumferences given in pole tables are at a fixed distance from the butt for all poles (6 feet from the butt per ANSI 05.1-1979). This must be converted to the ground line circumference. The basic equations follow.

$$C_g = \frac{(L_p - L_g)(C_b - C_t)}{(L_p - L_b)} + C_t \qquad \text{EQ V-4E}$$

Where:

C_g = Pole circumference at ground line

L_p = Length of pole

L_g = Distance from pole butt to ground line

L_b = Distance from pole butt to classification point per ANSI 05.1 (6 feet, per ANSI 05.1-1979) (2m, proposed metric value)

C_b = Pole circumference at distance L_b from butt per ANSI 05.1

C_t = Circumference at pole top

The resisting moment of the pole is found by the following equation:

$$M_r = K_r F_b C_g^3 \qquad \text{EQ V-4F}$$

Where:

M_r = Resisting moment at ground line, newton-meters or pound-feet

K_r = Calculation constant

K_r = 0.000 031 8, metric calculation, circumference in cm

K_r = 0.000 264, customary calculation, circumference in inches

F_b = Designated fiber stress, Pa (lb/ft²)

To calculate the maximum horizontal span, M_g in EQ V-4A is replaced by M_r and the moment equation is rewritten as:

$$S_h = \frac{M_r - M_p}{M_c} \qquad \text{EQ V-4G}$$

For customary calculations the values for M_r are available in the REA Staff Report "Dimensions and Resisting Moments of Wood Poles" or they can be calculated. For manual computations it is usually simplest to calculate and tabulate the various values of M_r, M_p, and M_c separately, then perform the simple equation given above.

Following is an example series of steps for calculating S_h based on the ANSI 05.1-1979 values. Figure V-10 illustrates the calculation. The example assumes a three-phase, Type C1 pole top assembly on a 35-5 Southern Yellow Pine (SYP) pole. The phase conductors are 266.8 kcmil (26/7) ACSR with a 1/0 (6/1) ACSR neutral, light loading district, and Grade C construction. Determine the maximum horizontal span using available customary data.

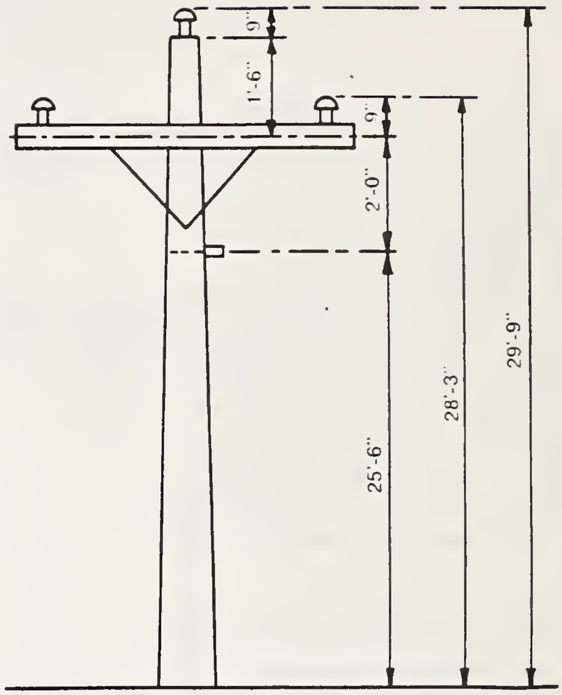


FIGURE V-10

Determine pole data from ANSI 05.1-1979 or REA Specification DT-5C. Obtain conductor data from Appendix B of this manual. Refer to Part II for NESC values of the design data for wind loading and overload capacity factors.

- **Tabulation of Data**

Pole Data

F_b = 8000 lb/ft²
L_p = 35 ft
L_g = 6 ft
L_b = 6 ft
H_p = 29 ft
C_t = 19 in
C_b = 29 in
K_r = 0.000 264
K_c = 72π

Design Data

W_p = 9 lb/ft²
F_{ow} = 2.00
F_{ot} = 1.33

Conductor Data

W_c = 0.4815 lb/ft (266.8 kcmil ACSR), phase conductor
W_c = 0.2985 lb/ft, (1/0 ACSR), neutral conductor

- **Ground Line Circumference**
  In this particular case $L_g = L_b$; therefore:

  $C_g = C_b$
  $C_g = 29$ in.

- **Resisting Moment of Pole** (EQ V-4F)

  $M_r = (0.000\,264)(8\,000)(29^3)$
  $M_r = 51\,500$ lb•ft

- **Conductor Moment Per Unit Length**

Phase	$W_c x H_c$	(EQ V-4B) $W_c H_c$
A	(0.4815)(28.25) =	13.60
B	(0.4815)(29.75) =	14.32
C	(0.4815)(28.25) =	13.60
N	(0.2985)(25.50) =	7.61
	$\Sigma(W_c H_c)$ =	49.13

$M_c = F_{ow}[\Sigma(W_c H_c)]$
$M_c = (2)(49.13)$
$M_c = 98.3$ lb•ft/ft

- **Moment Due to Wind on Pole** (EQ V-4D)

$$M_p = F_{ow} W_p \left(\frac{2C_t + C_g}{K_c}\right) H^2$$

$$M_p = (2)(9.0) \left(\frac{(2)(19)+29}{72\pi}\right) (29^2)$$

$M_p = 4484$ lb•ft

- **Maximum Horizontal Span** (EQ V-4G)

$$S_h = \frac{M_r - M_p}{M_c}$$

$$S_h = \frac{51\,500 - 4483}{98.3}$$

$S_h = 478$ ft
$S_h = 145.7$ m (478 ft)

A design and construction tolerance is generally not needed for horizontal span calculations since very few spans fall in a way to exactly fit the maximum span. Also the majority of poles will have a circumference larger than the minimum circumference for strength class. The NESC permits the averaging of the strength of three structures. While this is not a recommended design practice, it does provide additional construction tolerance.

The computations are repeated for other classes and heights of poles to provide the values for a pole strength table to be included in the staking design guide.

It should be noted that M_r is a function only of pole dimensions and fiber stress. Thus, once the values have been calculated, they can be retained and reused for any conditions of loads on the poles. The referenced REA Staff Report is an example of such a tabulation. Likewise, the values for M_p vary only with changes in the wind loading W_p and F_{ow}. Therefore, both M_r and M_p can be retained and used repeatedly for a specific system. Generally, for each design, three values of M_p are required, one for Grade C, one for Grace C crossings, and one for Grade B crossings. With the values of M_r and M_p precalculated, only the value of M_c needs to be determined to calculate S_h.

There is an alternate method of calculating $\Sigma(W_c H_c)$ which is useful in making calculations for a series of poles. If H_{cp} is equal to the distance from the conductor to the top of the pole, then:

$$\Sigma(W_c H_c) = (\Sigma W_c)(H_p) - \Sigma(W_c H_{cp}).$$

For a given conductor configuration and conductor sizes (ΣW_c) and $\Sigma(W_c H_{cp})$ are constant and only H_p changes as the pole height changes.

An example pole strength table based on the above example problem and expanded to other heights and classes of poles is provided in Chapter VI-4.

J. POLE STRENGTH CATEGORIES

The NESC defines and established transverse wind load overload capacity factors for three pole strength categories for tangent pole structures. These categories are Grade C, Grade C crossing, and Grade B crossing construction. REA Bulletin 40-7 requires that the distribution lines of REA borrowers be constructed to a minimum of Grade C construction and that the lines be constructed in conformance with the NESC. Thus pole strength data generally needs to be calculated and tabulated for three strength categories of tangent structures. If the basic design criteria selects a design overload capacity factor for increased reliability, this strength category replaces the Grade C category.

K. PREPARING THE POLE STRENGTH TABLE

There are many different ways to set up pole strength tables. Some utilities use master tables that may include designs for several conductor

sizes. With the increasing number of conductor sizes and types, and different conductor configurations being used, such a table becomes cumbersome and prone to error in application.

For staking design guides prepared for specific design packages, it is best to use a pole strength table which has span values which are for use only with the specific design.

The most common format for such a table is to use "pole class" for column headings and "pole length" as line headings. The table is set up in sections based on strength categories, with the range of pole lengths repeated for each strength category. Each section should clearly identify the strength category.

The table should include a design data section which clearly indicates the design variables needed to identify the line design for which the table is to be used. The table should include span adjustment factors and similar data for use with the table.

L. CALCULATION OF MAXIMUM SPANS AT SMALL ANGLES

The basic moment equations given previously provided for calculating moments due to line angles. For small angles that can be taken on unguyed poles the calculation can be simplified. For example, for a line angle of 5°, the cosine of half the angle is 0.999. Letting this equal one provides a very small tolerance and eases the computation.

The computation is made in the same manner as that given for the tangent structure except that M_t is included.

$$S_a = \frac{M_r - M_p - M_t}{M_c} \qquad \text{EQ V-4H}$$

Where:
S_a = Maximum angle wind span

M. SPAN REDUCTION FACTOR FOR LINE ANGLES

During staking operations, it is desirable to be able to determine the S_a from S_h since a table of values for S_h is usually available (Pole Strength Table). S_a can also be written as follows:

$$S_a = \left(\frac{M_r - M_p}{M_c}\right) - \left(\frac{M_t}{M_c}\right) \qquad \text{EQ V-4I}$$

$$S_a = S_h - \frac{M_t}{M_c}$$

$$S_a = S_h - K_t \sin(\theta/2)$$

Where:

$$K_t = \frac{2F_{ot}\,[\Sigma(T_cH_c)]}{M_c} \qquad \text{EQ V-4J}$$

K_t = Span reduction factor

For a given conductor configuration and tension design, this factor is a constant and can be calculated and included with the pole strength table of values of S_h. Or more simply, the span reduction can be calculated and tabulated for one or more small angles and the span reduction interpolated by the staker.

Following is an example of a calculation for span reduction due to line angle. The example is a continuation of the preceding example for determining S_h.

All other data is as given in the preceding example. Determine the span reduction factor and allowable span, with a line angle of one degree.

- **Tabulation of Data**

Phase conductor tension = 4500 lbs design tension
Neutral conductor tension = 1750 lbs design tension
F_{ot} = 1.33
θ = 1°

- **Moment Due to Conductor Tensions** (EQ V-4J)

Phase	$(T_c)(H_c)$		(T_cH_c)
A	(4500)(28.25)	=	127 125
B	(4500)(29.75)	=	133 875
C	(4500)(28.25)	=	127 125
N	(1750)(25.50)	=	44 625
	$\Sigma(T_cH_c)$	=	432 750 lb/ft

$$K_t = \frac{2F_{ot}\,[\Sigma(T_cH_c)]}{M_c}$$

$$K_t = \frac{(2)(1.33)(432\ 750)}{98.5}$$

$$K_t = 11\ 700$$

- **Maximum Horizontal Span** (EQ V-4I)

$S_a = S_h - K_t \sin(\theta/2)$

S_a = 478-(11 700)(sin 0.5°)
S_a = 376 feet
S_a = 114.6 m (376 ft)

N. POLE STRENGTH AT GUY ATTACHMENTS

When the guy attachment is located some distance below the conductor attachments, it is advisable to check for the pole strength at the guy

attachment. This calculation is made in the same manner as that for an unguyed pole except that the calculations are based on the circumference at the guy attachment and the heights above the guy attachment rather than at the ground line. The value for the cosine of half the line angle can be set at 1.0 in order to simplify the computation and to provide a design and construction tolerance.

CHAPTER V-5
GUY AND ANCHOR CALCULATIONS AND GUIDES

A. GUYED STRUCTURES

Guyed structures are used at angles, dead ends, and other locations in the line where the pole member of an unguyed structure, acting as a simple cantilever beam, is not capable of supporting horizontal design loads applied to the structure. Guyed structures are also used where the NESC specifically requires their use.

Distribution structures possess sufficient rigidity so that the guy and anchor assembly of a guyed structure can be considered as an integral part of the structure. The guy assembly is designed to hold the entire horizontal component of the load on the structure which lies in the direction of the guy. The wood pole is used as a strut and supports the vertical components of all loads on the structure including the vertical forces due to the tension in the guys.

The general application of guys and anchors in the staking of a distribution line is discussed in Part VI - Line Staking. This chapter describes the development of guy and anchor equations and guides for use by the line staker in staking the line. Equations presented may be used by the staker to calculate guying requirements when guying guides are not available.

B. STRENGTH REQUIREMENTS FOR GUYED STRUCTURES

The basis for the design of guyed pole structures is established by the NESC. The procedure for determining the strength requirements of the guyed structure is very similar to that for unguyed pole structures. The difference is that the force moments due to the applied loads are restrained by resisting moment of the guy assembly rather than by the resisting moment of the pole.

Like unguyed poles, the design loads are multiplied by overload capacity factors to derive the values of force used to calculate the required strength of the structure.

When the design loads are known, the required resisting moment of the guy assembly is used to determine the design of the guy assembly, and conversely, when the strength of the guy assembly is known, the resulting resisting moment of the guy assembly can be used to determine the permissible load on the structure.

The guy assembly is designed to withstand all force moments acting in the direction of the guy assembly. Therefore each horizontal force acting on the structure is resolved into vector components acting in line with, and perpendicular to, the direction of the guy assembly.

When guys are to be installed in more than one direction from the structure, this resolution of force vectors is done for each guy assembly.

C. OVERLOAD CAPACITY FACTORS

NESC overload capacity factors for guyed pole structures are given in NESC Table 261-5 and also in Table II-13 found in Chapter II-11 of this design manual.

As discussed in Chapter IV-11, the NESC overload capacity factors are generally used as the design overload capacity factors. Increased factors are used for those lines where increased reliability is needed.

For guyed structures, care must be taken that correct overload capacity factors are used as each type of design force requires use of a specific overload capacity factor. Overload capacity factors for determining guy strength differ from those used for pole strength; those for wind loads differ from those for conductor tension loads; and those for dead-end guys differ from those for bisector guys.

D. DESIGN LOADS

The source of the design loads is discussed in Chapter IV-11. The loads are based on the conductor loading and sag-tension data for the design ruling span. On occasion a basic structure design tension value is selected which dif-

fers from the conductor design tension. When such a value is given as basic design criteria, this value should be used in the structure design computations, otherwise, use the conductor design tension.

E. DIRECTION OF CRITICAL LOADING

In designing the guying for a supporting structure, there is a direction of wind loading which is most critical in determining the required strength of the guy assembly. When this direction is known, computations for the strength requirements need to be made only for this direction of wind loading.

Provided there is not a change in longitudinal tension of the conductor, the critical direction for tangent and angle guyed structures is with the wind in the transverse direction. For the tangent structure, the transverse wind loading is perpendicular to the line.

For the angle structure the critical direction of wind loading is in line with the bisector of the line angle. The transverse axis used for design and installation of the guy assembly is in line with the bisector.

For single dead-end structures, the critical direction of wind loading is in a direction perpendicular to the line. This direction causes the greatest dead-end tension load. The guy assembly is installed in and designed for the longitudinal direction.

For large angle structures which use dead-end assemblies in each line direction, the guying is designed as if the line in each direction were a single dead-ended line section. That is, the line is guyed and designed like a single dead-end in each line direction.

Where double dead-ended structures are used at tangent or small angle line locations, the critical direction of wind loading is in the transverse direction and the guying is designed the same as for undead-ended tangent and small angle structures. However, if there is a difference in conductor tension in the two dead-ended line sections, longitudinal guying is provided for this difference in longitudinal conductor tension.

Where attached conductors leave the structure in more than two directions as at tap poles, junctions, and service drops, the critical direction of wind loading has to be determined for each guy assembly.

F. CALCULATION OF GUY RESISTING FORCE

Once the load force vectors in the direction of the guy assembly have been determined, the summation of the force moments about the ground line are calculated. The force value needed to determine the strength of the guy assembly is the required horizontal component of guy resisting force at the point of guy attachment to the structure. This is found by using the following equation:

$$G_h = \frac{M_g}{H_g} \qquad \text{EQ V-5A}$$

Where:

G_h = Horizontal component of guy resisting force
M_g = Summation of ground line moments due to load forces
H_g = Height of guy attachment

For multiple guy assemblies, H_g is taken as the average height of guy attachment points.

G. GUY RESISTING FORCE FOR BISECTOR GUYS

For bisector guyed structures the summation of ground line moments is calculated by the same equation as used for unguyed pole structures. Substituting Equation V-4A into Equation V-5A results in Equation V-5B.

$$G_h = \frac{S_h M_c + M_t + M_p}{H_g} \qquad \text{EQ V-5B}$$

Where:

S_h = Horizontal span
M_c = Summation of moment loads due to wind on each conductor expressed as moment per unit length of span (EQ V-4B)
M_t = Summation of moments due to tension in each conductor at a line angle (EQ V-4C)
M_p = The moment due to the wind on the pole (EQ V-4D)

The computation is simplified and results conservative if in the calculation of M_c (Equation V-4B), the cosine of $\theta/2$ is set at one for all values of θ. This is recommended for manual calculations.

H. GUY RESISTING FORCE FOR DEAD-END GUYS

For dead-end guyed structures, the load force vectors consist of the structure design longitudinal conductor tensions. Equation V-5A can therefore be rewritten as shown by Equation V-5C.

$$G_h = \frac{M_t}{H_g} \qquad \text{EQ V-5C}$$

Where:

$$M_t = F_{ot}\,[\Sigma(T_cH_c)] \qquad \text{EQ V-5D}$$

Where:

F_{ot} = Overload capacity factor for longitudinal conductor tensions
T_c = Tension in each conductor
H_c = Height of each conductor attachment

I. DETERMINATION OF GUY LOAD

The resultant tension load applied to the guy and anchor assembly is:

$$G_r = \frac{G_h}{(\sin\theta)(F_g)} \qquad \text{EQ V-5E}$$

Where:

G_r = Resultant guy load, N (lb)
G_h = Horizontal force at guy attachment point, N (lb)
θ = Guy wire angle with respect to pole, degrees
F_g = Safety factor for guys = .9 by NESC

Since:

$$\sin\theta = \frac{L_g}{\sqrt{H_g^2+L_g^2}}$$

Where:

H_g = Height of guy attachment above ground
L_g = Guy lead, or distance from pole to anchor rod

The Equation V-5E can also be written as:

$$G_r = \frac{G_h\sqrt{H_g^2+L_g^2}}{F_gL_g} \qquad \text{EQ V-5F}$$

Equation V-5F is convenient when a calculator with trigometric functions is not available.

Assuming a 1:1 guy slope, or θ is equal to 45°, the resultant guy load or tension is:

$$G_r = G_h \div (0.9)(0.707)\ .$$

$$G_r = 1.57\ G_h \qquad \text{EQ V-5G}$$

J. DETERMINATION OF MINIMUM GUY LEAD

While it is recommended that 1:1 guy slope be used wherever possible, in some instances it is necessary to determine the minimum allowable guy lead for various guy and anchor arrangements.

The minimum allowable guy lead to the average anchor position is given by:

$$L_{ga} = H_g \tan\left[\arcsin\left(\frac{G_h}{G_uF_g}\right)\right] \qquad \text{EQ V-5H}$$

Where:

L_{ga} = Minimum allowable guy lead, m (ft)
H_g = Average guy attachment height, m (ft)
G_h = Horizontal force at average guy attachment point, N (lb)
G_u = The total guy breaking strength or total anchor holding power, whichever is less, N (lb)
F_g = Safety factor = 0.9 by NESC

Calculated minimum guy leads should be used only when it is not possible to obtain 1:1 guy slope and then the longest possible lead should be used.

It is common practice to increase calculated minimum leads from 0.2 m to 0.3 m (six inches to one foot) in order to allow for wind loading on structure accessories and a construction tolerance.

K. STRENGTH OF GUY WIRE AND ATTACHMENT HARDWARE

The breaking strength of guy wire is provided in Appendix B for guy wire included in REA Bulletin 43-5, List of Materials. The designated holding power of anchors in ordinary soil is given on REA construction drawings for anchor assemblies.

One of the most frequently overlooked strength requirements for guying is the strength of the components used in the guy attachment assembly. With the advent of larger conductors and high strength power driven screw anchors it has not been uncommon for utilities to also increase the strength of the guy strand but to continue use of the standard guy attachment hardware.

The strength of the attachment hardware used in REA standard guy units is shown on

page v of the List of Materials. The hardware can be assumed adequate only for use with the strongest guy strand included in the material list of the guy assembly construction drawing. If it is necessary to design heavier attachment units for large conductor designs it is suggested that strength data for the components be obtained from the manufacturers.

It also needs to be known that much of this hardware was designed for normal guy lead slopes and may not provide full rated capacity when used with short guy leads. Under these conditions it is also possible that the vertical bearing of the hardware on the wood pole may be excessive.

L. CALCULATIONS FOR MULTIPLE GUYS

Multiple guys or anchors are required where the strength of one guy cable or one anchor is not adequate for the load. Multiple guys may be placed two or more in line with each other or spread apart side-by-side.

When multiple guy attachments on the pole are relatively short distances apart, as is the case for most distribution structures, the simplest method for calculating guy strength and minimum guy leads is to assume that all guy and anchor assemblies are to be combined into one composite assembly attached to the pole at one point and to one anchor location. The pole attachment is assumed to be at the height above ground which is the average of all actual guy attachments and the anchor rod locations at a distance from the pole which is the average of all actual rods. The calculation is then made as if it were single guy and anchor using the equations given previously.

To determine the minimum guy leads required for a multiple guy combination calculate a resultant force at the average guy attachment point. Then divide this force by the number of guys and calculate the required guy lead to the average anchor location.

Figure V-11 may be used to determine the relationship of the average anchor location to the actual anchor locations for various anchor arrangements. The recommended minimum separation between rods is 1.5 m [5 ft].

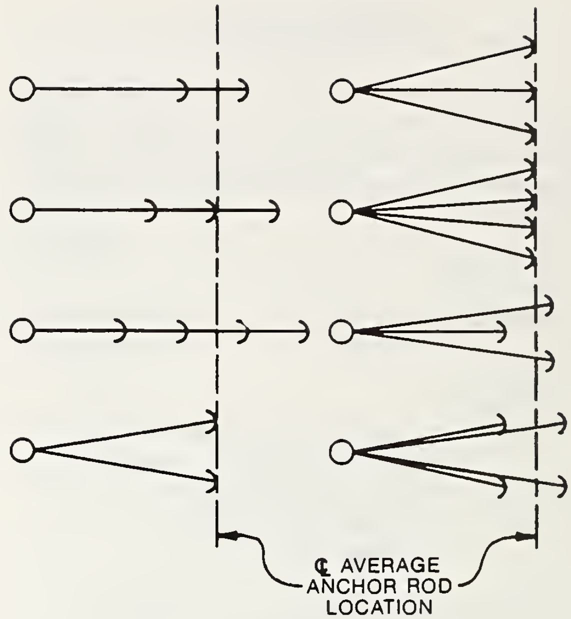


FIGURE V-11

M. EXAMPLE GUY ASSEMBLY CALCULATION

Figure V-12 illustrates the example which assumes a three-phase, type C3L pole top assembly on a 40-5 Southern Yellow Pine (SYP) pole. The phase conductors are 266.8 kcmil (26/7) ACSR with a 1/0 (6/1) ACSR neutral. Determine the strength requirements of the guy and anchor assembly for Grade C, Light Loading District construction. Because the majority of data is currently available only in customary units, the example is calculated in customary units and the results converted to metric units.

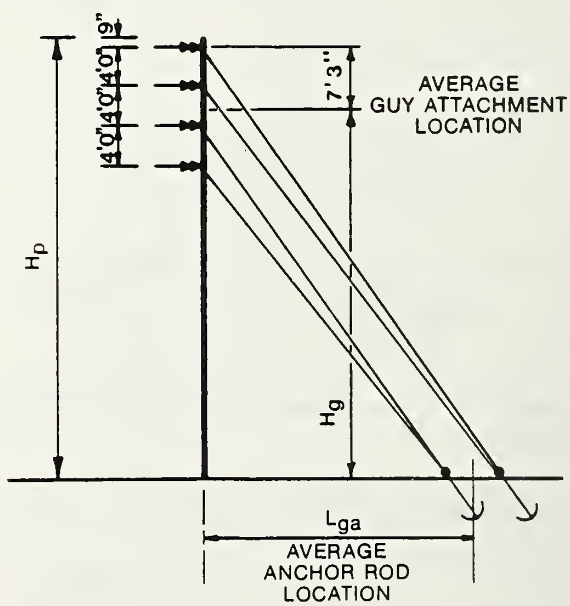


FIGURE V-12

- **Tabulation of Data**

Pole Data:

F_b = 8000 lb/in²
L_p = 40 ft
L_g = 6 ft
L_b = 6 ft
H_p = 34 ft
C_t = 19 in
C_b = 31 in = C_g
C_g = 31 in
K_r = 0.000 264
K_c = 72π

NESC Data:

W_p = 9 lb/ft²
F_{ow} = 2.00
F_{ot} = 1.15
F_g = 0.9

Conductor Data:

Conductor	W_c, lb/ft	W_v, lb/ft	T_c, lb
266.8 kcmil	.4815	.3673	4500
1/0	.2985	.1453	1750

Span data:

S_h = 400 ft

Line angle = 60°

$\theta/2$ = 30°

- **Wind on the pole surface:**

Use Equation V-4D:

$$M_p = (F_{ow})(W_p)\left[\frac{(2C_t+C_g)H_p^2}{K_c}\right]$$
$$= (2)(9)\left[\frac{((2)(19)+31)\ (34)^2}{72\pi}\right]$$
$$= 6347 \text{ lb}\bullet\text{ft}$$

- **Wind on the conductors:**

Use Equation V-4B:

$$M_c = F_{ow}[\Sigma(H_cW_c)]\cos 0/2$$

Phase	H_cW_c
A	(33.25)(0.4815) = 16.010
B	(29.25)(0.4815) = 14.084
C	(25.25)(0.4815) = 12.158
N	(21.25)(0.2985) = 6.343
	$\Sigma(H_cW_c)$ = 48.595

M_c = (2)(48.595)(cos 30°) = 84.169 lb•ft/ft

- **Resultant of conductor tensions:**

Use Equation V-4C:

$$M_t=(2)(F_{ot})[\Sigma(H_cT_c)]\sin(\theta/2)$$

Phase	H_cT_c
A	(33.25)(4500) = 149 625
B	(29.25)(4500) = 131 625
C	(25.25)(4500) = 113 625
N	(21.25)(1750) = 37 188
	$\Sigma(H_cT_c)$ = 432 063

$$M_t = (2)(1.15)(432\ 063)(\sin 30°)$$
$$= 496\ 872 \text{ lb}\bullet\text{ft}$$

- Average guy attachment height:

$$H_g = \frac{32.75+28.75+24.75+20.75}{4}$$
$$= 26.75 \text{ ft}$$

- Horizontal force at guy attachment:

Use Equation V-5B:

$$G_h = \frac{(400)(84.169)+496\ 872+6347}{26.75}$$
$$= 20\ 071 \text{ lbs}$$

- Required guy assembly strength:

Use Equation V-5G:

$$F_g = (1.57)(20\ 071)$$
$$= 31\ 511 \text{ lb for 1:1 guy slope}$$

From Figure V-12 it is seen that four guys are normally used. The required ultimate strength per guy is then:

$$\frac{31\ 511}{4} = 7885 \text{ lbs}$$

Therefore, 7/16-inch Siemens-Martin guys with an ultimate strength of 9350 lbs per guy would be adequate.

The required holding power of the composite anchor is also 31 543 pounds; therefore, either two 16 000 pound or four 8000 anchors will be adequate.

Thus, four 7/16-inch Siemens-Martin guy strands and two 16 000 lb REA F2-4 log anchors or four 8000 lb REA F1-2 anchors are satisfactory for use with the normal 1:1 slope guying. Where a reduced guy lead is necessary a calculation is made for minimum lead. It is apparent that the guys have access capacity but the anchors have essentially no extra capacity. A stronger anchor is therefore selected.

Assume that four 10 000 lb REA F1-3 anchors are to be used. What is the minimum allowable lead to the average anchor position?

The four guys have a total strength of:
9350 × 4 = 37 400 lbs

The four anchors have a total strength of:
10 000 × 4 = 40 000 lbs

Using this particular combination, the guy strength is most limiting and is used in Equation V-5H to determine the minimum lead.

$$L_{ga} = (26.75) \tan\left[\arcsin\left(\frac{20\,071}{(0.9)(37\,400)}\right)\right]$$
$$= 19.87 \text{ ft}$$
$$= 6.06 \text{ m } (19.87 \text{ ft})$$

After adding 0.2 m [0.5 ft] tolerance and rounding up the next 0.1 m [0.5 ft] the minimum lead becomes:

L_{ga} = 6.3 m [20.5 ft]

Figure V-11 is then used to select the actual placement of the four anchor rod locations for the most appropriate arrangement for the location where the guys are to be installed. The lead dimension is to the point where the anchor rod leaves the ground. The spacing between rods should not be less than 1.5 m [5.0 ft].

If the guy leads need to be further reduced, the guy and/or anchor strengths are increased by increasing the number or size. The calculation is then repeated.

N. DETERMINATION OF POLE CLASS TO SUPPORT VERTICAL LOADS

The column strengths of poles at guyed structures should be examined for loads on the pole due to the vertical weight of the conductor on the pole and the vertical component of the load supported by the guys. A guyed pole acts as a column sustaining these axial loads.

A pole acting as a column becomes unstable when the axial force becomes large enough to cause large lateral deflections.

Several assumptions are made in a column strength calculation. Among these assumptions is the height on the pole where the strength is most critical. The American Institute of Timber Construction suggests the critical area as the section of pole 1/3 the distance from the point of guy attachment to the groundline.

A factor of safety should be applied to the loads in this computation because of the assumptions made. REA Bulletin 62-1, Design Manual for High Voltage Transmission Lines, recommends a factor of safety of 2 as a minimum and striving for 3 at dead-ends.

- **Critical Vertical Load**

In general the critical axial load for the pole acting as a column is determined by the formula:

$$P_{cr} = \frac{\pi E A^2}{F_v K_c (K_u H_{gb})^2} \qquad \text{EQ V-5I}$$

Where:

P_{cr} = Critical buckling axial load, N (lbs)
E = Modules of elasticity of wood, Pa (lbs/in²)
A = Area of pole 2/3 of the distance from groundline to bottom guy attachment, cm² (in²)
K_c = Conversion constant, cm² to m² (in² to ft²)
= $4\text{x}10^8$ metric computation
= 576, customary computation
H_{gb} = Height of bottom guy attachment above ground m (ft)
K_u = The theoretical coefficient of unbraced length
= 0.7 for bisector guying
= 1.0 for tangent dead-end guying
F_v = Factor of safety
= 2 minimum

To derive the area of the pole at the critical point (1/3 the distance from the guy attachment to the ground line), solve the following equation:

$$A = \frac{1}{4\pi}\left[\frac{(C_b - C_t)(H_p - 0.667H_{gb})}{L_p - L_b} + C_t\right]^2 \qquad \text{EQ V-5J}$$

Where:

A = Area of pole 1/3 distance from guy attachment to ground line, cm² (in²)
C_b = Circumference of pole 1.83 m (6 ft) from the butt, cm (in)
C_t = Circumference of pole at top, cm (in)
H_{gb} = The distance from groundline to the bottom guy, m (ft)
H_p = Pole height above ground, m (ft)
L_b = 1.83 m (6 ft)
L_p = Pole height, m (ft)

- **Actual Vertical Loads**

The actual vertical loads are due to:

G_v, the vertical load due to the tension in the guy, N (lb)

$$G_v = \frac{(S_h)(M_c) + M_t + M_p}{L_g} \qquad \text{EQ V-5K}$$

Where:

M_c, M_t, and M_p are groundline moments and are defined in Chapter V-4

L_g = Length of guy lead, m (ft)
S_h = Horizontal span (1/2 the sum of adjacent spans), m (ft)

All overload capacity factors should be set equal to one when performing these calculations. Since groundline moments may also be calculated in Equation V-5A (which has overload capacity factors other than one) it may only be necessary to divide these previously calculated moments by the overload factors used to obtain the values necessary for substitution into Equation V-5J.

- W_c, the vertical load due to the vertical force (weight) of the conductors, N (lb)

$$W_c = (S_v)(\Sigma W_v) \qquad \text{EQ V-5L}$$

Where:

S_v = Distance between the low point of sags of the adjacent spans, m (ft)

W_v = Loaded vertical force of conductors per unit length, N/m (lb/ft)

Where spans are relatively short, the error will be small if the horizontal span, S_h, is substituted for S_v. The weight of crossarms, braces, insulators, and the pole above the bottom guy attachment point are usually neglected in calculations for distribution structures.

If $(G_v+W_v) \leq P_{cr}$ the selected pole class is adequate otherwise the pole class must be increased until the above relationship is true.

- **Example Calculation**

Determine the critical axial load for the guyed structure of the preceding example:

Use Equation V-5J:

$$A = \frac{1}{4\pi}\left[\frac{(31\text{-}19)(34\text{-}0.67\text{x}20.75)}{(40\text{-}6)}+19\right]^2$$
$$= 54.18 \text{ in}^2$$
$$= 349.6 \text{ cm}^2 \ (54.18 \text{ in}^2)$$

Use Equation V-5I:

$$P_{cr} = \frac{(\pi)(1\ 800\ 000)(54.18)^2}{(2)(576)\ [(0.7)(20.75)]^2}$$
$$= 68\ 299 \text{ lbs}$$

Use Equation V-5L, substitute S_h for S_v, and solve for W_c.

$$W_c = (400)\ [(3\text{x}0.367)+0.145]$$
$$= 498 \text{lb}$$

Use Equation V-5K and solve for G_v. Use the values of M_c, M_t, and M_p previously used in the guy strength calculations, but divide each value by the appropriate overload capacity factor to reduce the factor to one.

$$G_v = \left[\frac{(400)(84.169)}{2}+\frac{496\ 872}{1.15}+\frac{6345}{2}\right] \div 19.87$$

$$G_v = 22\ 751 \text{ lb}$$
$$G_v+W_c = 23\ 249 < 68\ 299$$

Therefore, the pole has adequate strength for vertical axial loads. However, if the average guy lead was reduced to 6.5 ft it would be found that the pole should be increased in class.

Experimentation with the preceding computation procedure will soon demonstrate that, for most distribution design, axial loading will not be a design problem provided normal 1:1 slope guying is used and the poles are equal in class or one class larger than the normal tangent pole class. Computations should be made where unusually tall poles require guying.

Special consideration should be given in areas subject to very heavy extreme ice or very high extreme wind loadings.

The factor which will have the greatest impact on axial loading of guy poles is reduced guy leads. The axial load will approximately increase by the reciprocal of the fraction of the normal 1:1 slope guy lead used for the guying. Thus, if lead is reduced to one-half of the normal, the axial load will approximately double. Or, if the lead is reduced to one-fourth of the normal lead, the axial load will be approximately four times that caused by normal guy leads.

CHAPTER V-6
SPAN LIMITATIONS BASED ON CONDUCTOR SEPARATIONS

A. CLEARANCES FOR CONDUCTORS ON THE SAME SUPPORTS

Chapter II-7 discussed the NESC clearance requirements between conductors carried on the same support. This chapter applies these requirements to the practical needs of the staking engineer.

These clearance requirements are covered under NESC Rule 235. The minimum clearance values covered under this rule are of two types, those which are to be maintained at the conductor supports and those which are to be maintained between the conductors in the span between the supports. In some cases, the minimum clearance values differ for these two conditions.

These clearance requirements are also categorized as horizontal or vertical requirements. The rule includes a diagonal clearance rule which simply requires that the separation between two conductors satisfy both the horizontal and the vertical requirements at any point in the span.

The REA standard pole top assemblies provide adequate clearance at the supports. However, certain minimum horizontal and vertical separations are required to be maintained throughout the conductor span. Some of these separations are a function of conductor sag. Since conductor sag varies with span length, essentially every span will have some value of length which will be limited by a clearance requirement. This will be true whether the two pole top assemblies are of like or unlike configuration. In some cases the allowable span will be far in excess of the practical span length based on other limiting factors. In other cases, the maximum allowable span may be surprisingly short. With REA standard pole top assemblies, the latter situation is most apt to occur in spans where the conductor changes configuration between supports. In a number of cases the span limit will be less than permitted by NESC requirements prior to 1977.

The staking guide should include a tabulation of the maximum allowable spans between those various combinations of two pole top assemblies which will be commonly encountered during the staking. In most cases these span limits will not be the most limiting condition, however, the staker needs to know this.

This chapter provides the equations and calculation procedures for determining these limiting span lengths. Some are quite simple to apply while others are complex and more applicable to computer or programmable calculator solutions. The chapter also provides some generic maximum span charts which will aid in determining the approximate values of maximum allowable spans where the conductor changes configuration between frequently used REA standard pole top assemblies.

B. CLEARANCES WHICH ARE FUNCTIONS OF CONDUCTOR SAGS

Span lengths which are limited by the clearances between two conductors are often determined by the sags of the conductors. These determinations generally involve an actual separation between the two conductors and a required minimum clearance. Either the separation or the required clearance may be a variable and is often a function of the conductor sag. As the span and sag increases the difference between the separation and the required clearance decreases until at some span limit they are equal.

When the design ruling span sag is known and the limiting sag condition can be defined, the maximum allowable span can be found by the following equation:

$$S_m = S_r\sqrt{\frac{D_m}{D_r}} \qquad \text{EQ V-6A}$$

Where:

S_m = Maximum allowable span
S_r = Design Ruling Span
D_m = Defined sag limit
D_r = Design ruling span sag

An equation which defines the sag limit can be substituted in Equation V-6A for D_m to provide an equation to determine the maximum allowable span. Thus this equation provides the basic form of many of the calculations for maximum spans based on conductor separations.

C. MAXIMUM SPANS BASED ON HORIZONTAL CLEARANCE REQUIREMENTS

The equations for permissible sag for a given horizontal separation were given by Equations II-7H and II-7I in Part II. These equations can be written as follows:

$D_m = 7.38(C_h - F_v)^2$ meters (for metric calculations)

$D_m = 2.25(C_h - F_v)^2$ feet (for customary calculations)

Where:

D_m = Maximum permissible final sag at 15°C [60°F], meters (feet)
C_h = Actual horizontal separation, meters (feet)
F_v = Voltage reduction factor
= 0.0076 m/kV, metric calculations
= 0.25 ft/kV, customary calculations

By substituting the equation for D_m into Equation V-6A, the following equations are obtained.

$$S_m = \frac{S_r(2.72)(C_h - F_v)}{\sqrt{D_r}} \text{ meters} \qquad \text{EQ V-6B}$$

$$S_m = \frac{S_r(1.5)(C_h - F_v)}{\sqrt{D_r}} \text{ feet} \qquad \text{EQ V-6C}$$

These two equations are used where the horizontal clearance is the limiting factor in determining the maximum span based on conductor horizontal separation.

Table V-5 provides values of F_V for voltages common to systems of REA borrowers. The voltage to be used is the conductor-to-conductor voltage between the two conductors which are most limiting.

TABLE V-5
VOLTAGE REDUCTION FACTORS

kV	F_V Meters	F_V Feet
7.2	0.055	0.18
12.5	0.095	0.31
14.4	0.109	0.36
19.9	0.151	0.50
24.9	0.186	0.62
34.5	0.262	0.86

The preceding equations are valid only if the value of C_h is greater than the basic horizontal clearance at the support. REA standard pole top assemblies are designed to satisfy this requirement. For spans between two Type C1 or two Type C9 pole top assemblies, this clearance requirement will not generally be the most limiting of the various span limiting factors. These equations are useful for determining whether the structures provide adequate spacing for long crossing spans.

When these equations are used for spans between pole top assemblies of unlike configuration but where the two conductors are subject to the horizontal clearance requirement throughout the span, C_h is determined by the separation at the more restrictive support.

- **Sample Calculation**

Find the maximum allowable span based on horizontal separation for a 24.9/14.4 kV, REA Type VC9 pole top assembly. The conductor spacing on both sides of the crossarm is 940 mm (37 in). The design ruling span of the conductor is 160 meters and the ruling span sag at 15°C is 1.83 meters.

The conductor spacing on both sides of the crossarm is the same, therefore, the minimum phase-to-phase spacing is the same as the minimum phase-to-neutral spacing and the phase-to-phase voltage of 34.5 kV will be most restrictive. From Table V-5, F_V is found to be 0.262 meters. Substitute the values into Equation V-6B for a metric solution.

$$S_m = \frac{(160)(2.72)\,(0.940-0.262)}{\sqrt{1.83}}$$

$$= 218 \text{ m } (715 \text{ ft})$$

D. MINIMUM HORIZONTAL CLEARANCES

The preceding determination of maximum allowable spans is applicable only when the horizontal clearance requirements control between two conductors throughout the span. The minimum horizontal clearance between two conductors becomes a factor in determining maximum spans when the conductors change configuration such that the controlling clearance requirement changes from the horizontal clearance to the vertical clearance at some point in the span. In such cases, it is necessary to determine the minimum allowable horizontal clearance.

The equations for minimum horizontal clearance as a function of voltage and conductor sag are given below:

$$C_{hm} = 0.025\,(\text{kV}) + 0.667\sqrt{D}\ \text{ft} \quad \text{EQ V-6D}$$

$$C_{hm} = 0.0076\,(\text{kV}) + 0.368\sqrt{D}\ \text{m} \quad \text{EQ V-6E}$$

Where:

C_{hm} = Minimum horizontal clearance
kV = Conductor-to-conductor voltage in kilovolts, except that for voltages below 8.7 kV, use (kV-8.7) =0.
D = Final 15°C[60°F] sag in span, m (ft)

These equations are a factor in the determination of the point in the span where the controlling clearance changes.

E. MAXIMUM SPANS BASED ON VERTICAL CLEARANCE REQUIREMENTS

The required NESC vertical clearance should be maintained between any two conductors in any portion of the span where the required horizontal clearance is not provided.

The vertical clearance requirements between two conductors with unlike sags differ from the requirements between two conductors with like sags. Therefore, these two conditions are treated separately.

1. Conductors with Equal Sags

Table II-7 of Chapter II-7 (NESC Table 235-5) presented the required NESC vertical clearances at the supports between line conductors. If the sags of two conductors are the same, these clearances should be maintained at all points in the span. This would generally be the case for two phase conductors of the same circuit.

If the sags are equal and the minimum vertical clearance is maintained or exceeded at the supports at each end of the span, the length of the span will not be limited by vertical clearance requirements. All REA standard pole top assemblies are designed to meet this requirement when the supports at both ends of the spans are of the same type.

2. Conductors with Different Sags

For distribution phase conductors located above the neutral, for distribution conductors underbuilt below transmission conductors or below another distribution circuit, and for distribution secondaries or communication cables below distribution primary circuits, the conductor sags will most likely be different. The difference in sags may be due to difference in sag characteristics or due to differences in the operating temperatures of the conductors.

The clearance requirements may differ for various combinations given above. This discussion will be limited to the requirements for a distribution phase conductor located above the associated neutral conductor. The concepts presented can be adapted to the rules covering other conductor pair combinations.

The vertical clearance requirements are applied with the upper phase conductor sag determined at the maximum operating temperature or 50°C [120°F], whichever is greater. The lower phase conductor sag is determined at an operating temperature of 15°C [60°F].

The required vertical clearance at any point in the span should not be less than 75 percent of the basic required vertical clearance at the support as given by Table II-7.

The actual vertical separations between conductors along the span will be a function of the sags of both conductors. The difference in sags of the two conductors will vary as a function of the square of the span length.

Any variation of actual sags from the predicted sags for either conductor will result in actual separations other than predicted. This variation will be greater for long spans than for short spans. It is therefore recommended that a design tolerance be included and in such a manner that it is a function of span length. This is done by adding the tolerance to the design ruling sag value of the upper conductor.

Equation V-6F is used to determine the allowable span based on vertical separation when the vertical separations at the two supports are the same but the conductor sags are different.

$$S_m = S_r\sqrt{\frac{V-C_v}{D_{um}+C_t-D_b}} \qquad \text{EQ V-6F}$$

Where:

S_m = Maximum span based on vertical separation, meters (feet)
S_r = Design ruling span
V = Vertical separation at supports
C_v = Required vertical clearance
= 75% of required clearance at support
D_{um} = Final ruling span sag of the upper conductor at its maximum operating temperature or 50°C [120°F] which ever is greater
D_b = Final ruling span sag of bottom conductor at 15°C [60°F]
C_t = Clearance tolerance

If the vertical separations at the supports are different, Equation V-6G should be used.

$$S_m = S_r\left[\frac{\sqrt{V_1-C_v}+\sqrt{V_2-C_v}}{(2)\sqrt{D_{um}+C_t-D_b}}\right] \qquad \text{EQ V-6G}$$

Where:

V_1 = Vertical separation at Support 1
V_2 = Vertical separation at Support 2

• Sample Calculation

Find the maximum allowable span based on vertical separation for a 24.9/14.4 kV, REA Type VC1 pole top assembly. It is obvious the vertical separation requirement will apply to the center phase conductor and the neutral. The separation at the supports is 1.30 m (4.25 ft). The design ruling span is 100 meters and the ruling span sag of the phase conductor is 1.56 meters at the maximum operating temperature. The ruling span sag of the neutral is 1.05 meters at a normal temperature of 15°C [60°F]. A construction tolerance of 0.075 meters (3 inches) is recommended.

Since the vertical separations at both supports are the same, use Equation V-6F. From

Table II-7, the required clearance at the support is 0.41 meter.

$$C_v = (0.41)(0.75)$$
$$= 0.3075 \text{ m}$$
$$S_m = (100)\sqrt{\frac{1.3-0.3075}{1.56+0.075-1.05}}$$
$$= 130.2 \text{ m (427 ft)}$$

In the event the allowable span based on standard spacing is not long enough, the neutral may be lowered on the pole to increase the vertical separation. The required vertical spacing to achieve a desired span S_d, is given by Equation V-6H.

$$V_d = \left(\frac{S_d}{S_r}\right)^2 (D_{um}+C_t-D_b)+C_v \qquad \text{EQ V-6H}$$

Where:

V_d = Required vertical separation for desired span meters (feet)

S_d = Desired span length

- **Sample Calculation**

Using the data from the previous example, determine the required vertical separation to allow a 150 meter span.

$$V_d = \left(\frac{150}{100}\right)^2 (1.56+0.075-1.05)+0.3075$$
$$= 1.62 \text{ m (5.3 ft)}$$

Since the normal separation is 1385 mm, in this particular case, the neutrai would have to be lowered 235 mm (9.25 in).

F. MAXIMUM SPANS BASED ON DIAGONAL CLEARANCES

NESC Rule 235D., which covers diagonal clearances, simply requires that both vertical and horizontal clearance requirements be maintained at the supports and throughout the span. The REA standard pole top assemblies satisfy both vertical and horizontal requirements at the support and provide separations such that reasonably long spans can be used. However, the NESC rules are more restrictive than the rules prior to 1977 and in some cases, the allowable span lengths may be considerably shorter.

The preceding equations have both provided methods for determining the maximum allowable spans based on both vertical and horizontal requirements. When the separation between two conductors has both vertical and horizontal components, these rules are applied simultaneously.

When the conductor span is between two supports with identical configurations, the allowable spans based on some conductor pairs may be limited by the horizontal clearance requirements while other pairs may be limited by the vertical requirements but each pair will be limited by only one of the requirements. One pair will be most limiting in determining the maximum span. Generally, it will be obvious which pair will be most limiting due to the horizontal requirement and which pair will be most limiting to the vertical requirement. Therefore, usually only two computations are required and the computations are relatively simple.

When the conductors change configuration between two supports, the calculations become more complex and considerably so if at some point in the span the controlling clearance changes from the horizontal to the vertical clearance requirement. This situation often occurs at angles or dead ends where it becomes necessary to roll some of the conductor pairs from a horizontal to a vertical configuration. Figure V-13 shows one typical example of such a roll.

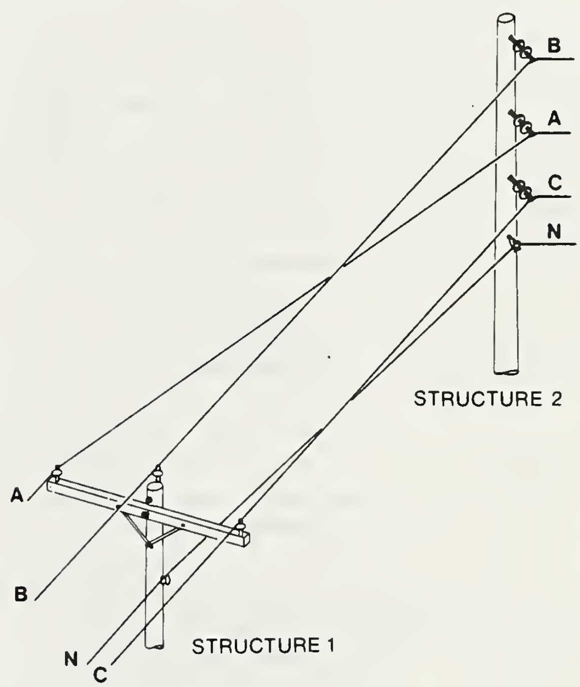


FIGURE V-13

It can be seen that some conductor pairs will be controlled by one clearance requirement for a portion of the span and by the other for the remainder of the span. It is not obvious which clearance will limit the span length or at what point in the span the limiting condition will occur. The calculation of the allowable span is complicated because the separations vary throughout the span. The maximum span may be limited by any pair of conductors and either clearance requirement. The span may be limited by a phase-to-phase pair of conductors or by a phase-to-neutral pair. Thus, for a three phase line, the span will be determined by the most limiting of any of the six pairs of conductors. Because the magnitudes of the controlling clearances differ, it is not always obvious which pair will limit the span length.

The first step in the procedure for determining the maximum span is to sort out those pairs which will be limited by either the horizontal or vertical clearance throughout the span and to determine the most limiting of these pairs.

The second step is to select from the remaining pairs. those which are phase-to-phase pairs and determine the most limiting span based on these pairs. The calculation method is given hereafter.

The third step is to determine the most limiting span for those phase-to-neutral conductor pairs which are subject to the diagonal clearance rule. These computations will be the most complicated of all and in most cases, one of these pairs will probably determine the most limiting of the allowable spans. The calculation method is given hereafter.

An examination of Figure V-13 will show that more than one roll configuration is possible between these two structure types. It is normal practice for the center phase conductor to go to the top position at the stacked corner structure. However, it is seen that the two outside phase conductors can roll either way. Usually the utility will have a standard policy concerning the orientation of the phase conductors and this should be considered in determining the maximum allowable span. What may be of greatest importance is the relationship between the bottom phase conductor and the neutral. Commonly the neutral is carried on the road side of the pole line. Thus, the neutral may be on either side of the pole when approaching a corner pole. The neutral can also be on either side of the pole at the corner depending on the direction of the turn. It can be seen that in some cases the neutral can cross under the closest phase conductor and in other cases it will not. Generally, the span will be more limited when the neutral crosses under the phase and this configuration should be used in the computation.

G. MAXIMUM SPANS LIMITED BY PHASE-TO-PHASE ROLLS

Since the sags of any two phase conductors of the same circuit are assumed to be equal, the maximum span based on any two phase conductors is limited only by the configuration geometrics and the required vertical and horizontal clearances.

If any particular pair of phase conductors has the required vertical separation at both supports, the horizontal separation is not a factor and the span will not be limited by this pair.

If any particular pair of phase conductors has the required horizontal separation at both supports, the maximum span based on this pair will be limited only by the smaller of the two support separations and determined by Equation V-6B or V-6C.

If the separation of any pair of phase conductors is controlled by the vertical clearance at one end of the span and by the horizontal clearance at the other, the maximum span based on this pair is determined by Equation V-6I given below:

$$S_m = \left(\frac{(K)(S_r)}{\sqrt{D_r}}\right)\left[\frac{H_1(V_2-C_V)-H_2(V_1-C_V)}{(V_2-V_1)} - F_V\right]$$

EQ V-6I

Where:

S_m = Maximum allowable span, m (ft)
K = Calculation constant
= 2.72 (metric calculation)
= 1.5 (customary calculation)
S_r = Design ruling span, m (ft)
D_r = Phase conductor final rulings span sag at 15°C (60°F), m (ft)
H_1 = Horizontal separation at support 1
H_2 = Horizontal separation at support 2
V_1 = Vertical separation at support 1
V_2 = Vertical separation at support 2
C_V = Required vertical clearance from Table II-7,
F_V = Voltage factor

Since it is assumed that the phase conductors were originally sagged together and have been

subjected to the same operation conditions, it should not be necessary to include a design tolerance to these conductor separations.

• **Sample Problem**

Determine the maximum allowable span for the most restrictive pair of phase conductors for a configuration roll from an REA Type C1-2 pole top assembly to an REA Type C3 pole assembly as shown by Figure V-13. The nominal line operating voltage is 12.5/7.2 kV. By observation it can be seen that Phases A and B will be the most restrictive pair of phase conductors.

The metric dimensions given below include soft conversions from customary dimensioned pole top assemblies.

S_r = 120 m
D_r = 1.222 m
H_1 = 1.015 m
H_2 = 0.0 m
V_1 = 0.405 m
V_2 = 1.220 m
C_V = 0.410 m
F_V = 0.095 m

Use Equation V-6I to determine the maximum allowable span.

$$S_m = \left(\frac{(2.72)(120)}{\sqrt{1.222}}\right) \times \left[\frac{(1.015)(1.22-0.41)-(0)(0.405-0.41)}{(1.22-0.41)} - 0.095\right]$$

S_m = 271.6 m (981 ft)

H. MAXIMUM SPANS LIMITED BY PHASE-TO-NEUTRAL ROLLS

The sags of the phase and neutral conductors usually differ and this complicates the calculations of diagonal clearances between phase-to-neutral pairs of conductors. The vertical clearance portion of the diagonal clearance determination is subject to the same conditions as discussed in Section E of this chapter where the vertical clearances controlled the separation throughout the span.

The procedure discussed hereafter pertains only to those phase-to-neutral pairs of conductors subject to the diagonal clearance rule. Maximum span determinations for phase-to-neutral pairs for which either the vertical clearance or the horizontal clearance requirement controls throughout the span should be made with the simpler methods given previously in this chapter.

Where the separation of the phase-to-neutral pair of conductors is controlled by vertical clearance requirements at one end of the span and by horizontal clearance requirements at the other end of the span, the maximum allowable span is determined by the simultaneous application of horizontal and vertical clearance requirements. This determination of the span limit is complicated as the maximum span based on both the vertical clearance controlled portion and the horizontal clearance controlled portion of the span are functions of the conductor sags which in turn are functions of the maximum span. Thus the determination is best accomplished by repeated trial computations based on assumed values which converge on the actual maximum span value. This type of calculation is best done with a computer or a programmable calculator which has the capacity for a convergence subroutine. It can be done manually and the procedure is demonstrated hereafter.

When this determination is done manually, the allowable spans based on all other pairs of conductors should be calculated first and the most restrictive of these span limits selected. This selected span limit is then used in the first trial calculation as the assumed maximum span value. If the clearance calculations based on the selected span limit indicate that a longer span could have been assumed, no further calculations need to be performed since the selected span limit remains the most restrictive. If the calculations indicate that a shorter span must be assumed, then the procedure should continue until the assumed span results in horizontal and vertical conductor clearances which are met, but not exceeded.

The procedure for determining the diagonal clearance span limit by the manual method follows.

• **Step 1**

Determine all span limits that can be calculated by the previous methods. Select the most restrictive of these span limits.

• **Step 2**

Select an arbitrary span length. Normally this should be the most limiting of the maximum span values found under Step 1, otherwise select the maximum span desired.

• **Step 3**

The greater of either the phase or neutral conductor final ruling span sags at 15°C [60°F] is

used to calculate the most restrictive 15°C [60°F] sag for the assumed maximum span. Use Equation V-2A for the calculation.

$$D_m = D_r\left(\frac{S_m}{S_r}\right)^2$$

- **Step 4**

Calculate the minimum required horizontal clearance, C_{hm}, for the selected maximum span. Use Equation V-6D or V-6E.

- **Step 5**

Calculate the location in the span where the actual horizontal separation equals the required horizontal clearance for the given pair of conductors. Refer to Figure V-14. X is the fraction of the span length away from Structure 1 to where the horizontal separation between the conductors equals C_{hm}. Equation V-6J is used for the calculation.

$$X = \frac{H_1 - C_{hm}}{H_1 - H_2} \qquad \text{EQ V-6J}$$

Where:

X = The fraction of the span length to the point where $H_x = C_{hm}$

H_x = Horizontal separation at any point in the span

C_{hm} = Minimum required horizontal clearance from Step 4

H_1 = Horizontal separation at Structure 1

H_2 = Horizontal separation at Structure 2

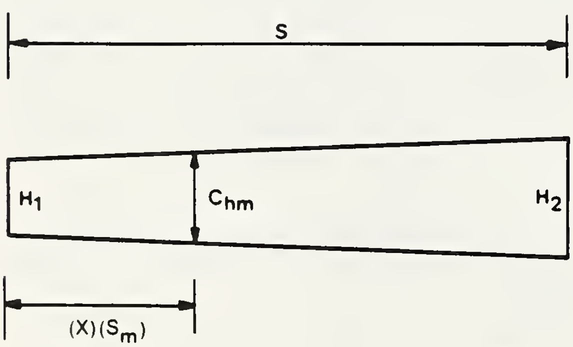


FIGURE V-14

- **Step 6**

Calculate the actual vertical separation at the location in the span determined in Step 5. Refer to Figure V-15 and use Equation V-6K.

$$V_x = V_1 + X(V_2 - V_1) - \left(\frac{S_m^2}{S_r^2}\right)(D_{um} + C_t - D_b)(4)(X - X^2) \qquad \text{EQ V-6K}$$

Where:

V_x = Vertical separation at point X

V_1 = Vertical separation at Structure 1

V_2 = Vertical separation at Structure 2

D_{um} = Final ruling span sag of the upper conductor at its maximum operating temperature or 50°C [120°F], whichever is greater

C_t = Design tolerance

D_b = Final ruling span sag of the lower conductor at 15°C [60°F]

X = Fraction of span length determined in Step 5

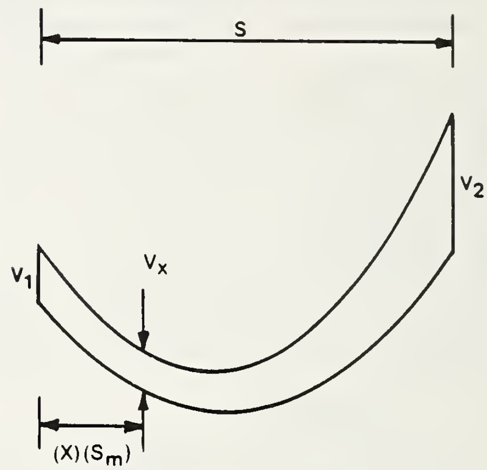


FIGURE V-15

- **Step 7**

Compare the actual vertical separation determined by Step 6 with the required vertical separation, C_V. For a phase over neutral separation, C_V is equal to 75 percent of the value of C_V as given in Table II-7 (NESC Table 235-5).

If the calculated value for the actual vertical separation is equal to or slightly greater than the required vertical separation, the assumed value for the maximum span, S_m, is used as the maximum allowable span.

If the actual vertical separation is greater than required, assume a new value for S_m which is greater than the preceding value and return to Step 3.

If the actual vertical separation is smaller than required, assume a new value for S_m which is smaller than the preceding value and return to Step 3.

• **Sample Problem**

Continue with the sample problem used for phase-to-phase separations in Section G. The data required for this determination is as follows:

S_r = 120 m
D_r = 1.222 m (the phase conductor has the greater sag)
H_1 = 0.863 m
H_2 = 0.305 m
V_1 = 0.838 m
V_2 = 1.220 m
C_{hm} = 0.305 m
D_{um} = 1.872 m
D_b = 1.207 m
C_t = 0.075 m.
C_v = (0.75)(0.41) = 0.308 m

A review of this data shows that the vertical separations at both supports exceeds the minimum required vertical clearance, C_v. It is therefore known that the maximum allowable span will be at least as long as permitted by the vertical separation and longer if the limiting portion of the vertical separation occurs where there is adequate horizontal separation. Because Equation V-6F is much simpler to calculate than Equation V-6K, it is wise to first determine the maximum span based vertical separation. Using Equation V-6F, make this determination.

In some cases this value may be adequate to use as the maximum allowable span and the determination for the actual longest maximum allowable span can be terminated. If a longer maximum span is desired the calculation continues to Step 2. It is seen that the value calculated using Equation V-6F is the minimum span length which needs to be used as a trial maximum span. It is suggested that some longer span value be used in the first trial in order to establish an upper and lower limit to the range of spans. In this case a span value of 150 meters is selected for the first trial.

Table V-6 is a tabulation sheet prepared to assist in the evaluation and demonstrate the iteration process, as the range of trail spans is progressively reduced. The trial maximum spans are tested using the steps given above. For the sample problem the progressive trial spans used were 150, 125, 135, and 130. Note that for each trail the difference between the vertical separation and the required vertical clearance reduces until at a span of 130 meters the difference is zero.

From the computation sheet it is seen that V_x-C_v converges at a span length of 130 meters therefore:

S_m = 130 m (426 ft)

It can be seen that judicious choice of trial spans can reduce the number of computations required. It can also be seen that a means of estimating the allowable span reasonably close can also reduce the number of trials required. One method that can be used for such estimating is the use of generic maximum span charts which are described hereafter. Such charts, when properly used, will provide answers within 3 meters (10 ft) accuracy. If the maximum span appears to be critical, the above procedure can be used to refine the answer.

I. PREPARATION OF GENERIC MAXIMUM SPAN CHARTS

By repeated application of the preceding calculation methods it is possible to prepare maximum span calculation charts which are generic in the sense that for a defined change in configuration between supporting structures and for a specific line voltage, the charts can be used to determine approximately the maximum span for any design ruling span and ruling span sag condition. As shown by Figure V-16, the charts plot the maximum allowable span versus difference in sags, ΔD, for a family of 15°C [60°F] sags.

TABLE V-6
SAMPLE PROBLEM COMPUTATION SHEET

Trial Span	Step 3 D_m, m	Step 4 C_{hm}, m	Step 5 X	Step 6 V_x, m	Step 7 V_x-C_v, m
150	1.909	0.564	0.537	-0.107	-0.415
125	1.326	0.479	0.689	0.412	+0.104
135	1.547	0.513	0.628	0.203	-0.105
130	1.434	0.496	0.658	0.308	0.000

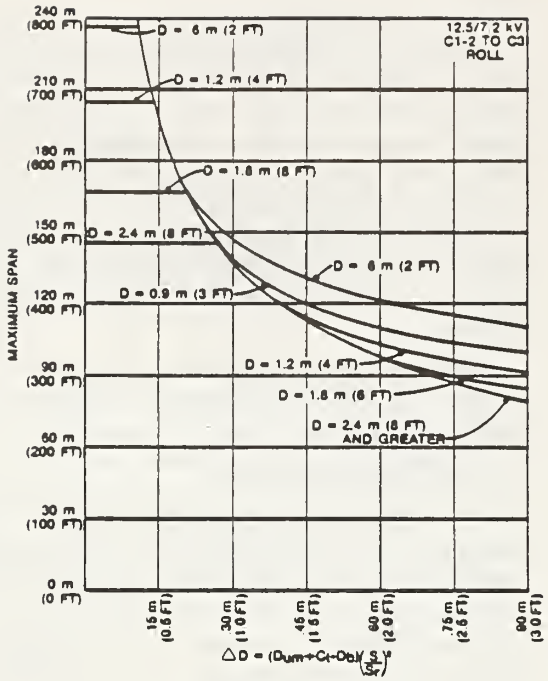


FIGURE V-16

The preparation of such charts is tedious when done by manual calculation methods and is recommended only for those configuration changes which will be encountered repeatedly. The method of preparation is given here and should also be studied in order to better understand the application of the generic maximum span charts that are included with this design manual.

Each chart is based on an arbitrarily selected reference ruling span together with a group of ruling span sag values selected in regular rounded increments which will permit easy interpolation between the sag values. The charts can be used to determine maximum spans in either the metric or the customary system of units. The selection of rounded values should be based on the system of units for which the charts will be most frequently used. The reference ruling span of Figure V-16 is 91.5 m (300 ft) and the sag increments are 0.6 m [2.0 ft]. The charts included in Appendix D of this design manual are based on the same reference values.

In the application of the charts, the actual design ruling span sag values are converted to sag values for a span length equal to the reference ruling span of the chart. These converted values are located on the charts by interpolating between two curves of the family of incremental sag curves. The application procedure is covered in detail in the next section of this chapter.

The procedure for preparing a chart for a specific configuration change and line voltage is described by the steps given below. It is suggested that Figure V-16 be used as an aid in following the procedure.

- **Step 1**

  Select an appropriate reference ruling span. A rounded value should be used which is based on the system of units most frequently used in the calculation of maximum spans. The value should approximate the actual design ruling span values encountered on the utility system.

- **Step 2**

  Select a rounded value to be used as the incremental difference in sag for the family of ruling span sag curves. The value should be in the same system of units as used for the reference ruling span selected in Step 1. A value of 2.0 ft was used for Figure V-16.

- **Step 3**

  Select a reference ruling span sag which will represent a 15°C [60°F] final sag in the calculations. For the first set of computations the smallest increment based on Step 2 is suggested. For Figure V-16 this value was 2.0 ft. For succeeding sets of computations increase the value by one incremental step. In the computations this value will be used for D_r. On the charts it is identified as D.

- **Step 4**

  Using the value of D_r from Step 3, calculate the maximum span for the most restrictive pair of phase conductors using Equation V-6I. The resulting span length is plotted as a horizontal line on the chart since it is independent of any differences in sag. For the first set of computations, this line is shown at a span length of approximately 780 feet on Figure V-16.

- **Step 5**

  Using the value of D_r from Step 3, calculate the maximum span values for phase-to-neutral separations as required to plot the incremental ruling span curve D on the chart. Use the procedure described by Step 1 through 10 as discussed in Section H of this chapter. The value of the maximum span, S_m, is plotted on the charts as a function of difference in phase and neutral conductor sags, ΔD. Therefore, ΔD replaces the

term $(D_{um}+C_t-D_b)$ where it appears in the computation procedure. The values of S_m as a function of ΔD are plotted up to but not exceeding the value of S_m calculated under Step 4 above. On Figure V-16 the increments used for ΔD were 0.5 feet.

- **Step 6**

Return to Step 3, increasing the value of D_r by one increment as defined in Step 2. Repeat the procedure until the desired range of the family of sag curves D has been plotted on the chart.

If the required phase-to-neutral clearance, C_v, is provided at both structures, Equation V-6G can be used to calculate S_m as a function of ΔD and plotted on the chart. This curve is asymptotic in nature in that the curves calculated and plotted under Step 5 above eventually merge into this curve. In a sense, the asymptotic curve defines the lower practical limit of the family of ruling span curves.

As the family of curves approach the asymptotic curve the separation between the curves decrease and it may be necessary to increase the magnitude of the incremental steps between the curves.

The data required to prepare a generic maximum span chart can be calculated quite easily by an electronic computer. However, for those with such equipment available, there is little point in doing so since the program is simply a minor variation of a program which will calculate the maximum span directly without the aid of charts.

J. APPLICATION OF THE GENERIC MAXIMUM SPAN CHARTS

Figure V-16 and the charts included in Appendix D are generic maximum span charts which simplify the determination of the allowable maximum spans where the conductors roll from one configuration to another between two structures. Each chart is prepared for a specific pair of top assemblies and for one nominal line operating voltage. The preparation of the charts is described in the preceding section of this chapter.

The charts included are for those most frequently encountered three phase rolls from the basic tangent structures (REA types C1-2 and C9-2) to the most common stacked angle structures (REA types C3 and C4). They can also be used for other structure types of the same configurations. Charts have been included for the nominal three phase line voltages of 12.5/7.2 kV and 24.9/14.4 kV. Maximum span computations for less frequently used configurations and voltages can be made by the methods described earlier in this chapter.

The results obtained by use of the charts must be considered approximate. Trial use of the charts will show that even with careful use it will be difficult to read maximum span values within 3 m [10 ft]. In spite of the fairly poor accuracy the charts have two uses of value. First, the chart provides a means for determining quickly whether the maximum span is a matter of concern. If the span is found to be longer than practical to use for other reasons, there is no real reason to pursue the determination further. Secondly, if the maximum span is found to be critical, the approximate answer can be used as the arbitrary span value in the procedure given in Section H of this chapter. The approximate value will be very close to the final answer obtained by that method and should reduce the number of trials required by that method.

The procedure for using the charts is simple and consists primarily of converting actual design ruling span sag values to the sag values for a span length equal to the reference span length used in preparation of the charts. For the charts included with this design manual the reference span length is 91.5 m (300 ft). The procedure is given below.

- **Step 1**

Convert the actual 15°C [60°F] final ruling span sag to the sag value for the reference span length. Use Equation V-6L.

$$D = D_r\left(\frac{S}{S_r}\right)^2 \qquad \text{EQ V-6L}$$

Where:

D = Final 15°C [60°F] sag in a 91.5 m (300 ft) span

D_r = The greater of either the upper or lower final ruling span sag at 15°C [60°F]

S = 91.5 m (300 ft)

S_r = Actual design ruling span, m (ft)

- **Step 2**

Convert the difference between the phase and neutral sags at the actual ruling span to a difference value for the reference span length. Use Equation V-6M.

$$\Delta D = (D_{um}+C_t-D_b)\left(\frac{S}{S_r}\right)^2 \qquad \text{EQ V-6M}$$

Where:

ΔD = Difference in the upper and the lower sags for the reference span length

D_{um} = Final ruling span sag of the upper conductor at its maximum operating temperature or 50°C [120°F], whichever is greater, m (ft)

D_b = Final ruling span sag of the lower conductor at 15°C [60°F], m (ft)

C_t = Design tolerance, m (ft)

- **Step 3**

Select appropriate chart. Enter the chart on the x-axis at the value of ΔD calculated at Step 2. Proceed vertically and intersect the appropriate sag curve D as calculated at Step 1. Interpolate as necessary between two sag curves.

- **Step 4**

Determine the maximum span value by projecting the point horizontally to the y-axis and reading the corresponding value for the maximum span.

- **Sample Problem**

Determine the maximum allowable span for a configuration roll from a tangent structure with an REA type C1-2 pole top assembly to an angle structure with an REA type C3 pole top assembly. The nominal operating voltage of the line is 12.5/7.2 kV. Refer to Figure V-13 for the roll configuration.

Assume the following values for the actual ruling span and ruling span sags:

S_r = 120 meters
D_r = 1.222 meters
D_{um} = 1.872 meters
D_b = 1.207 meters

Using Equation V-6L, calculate D

$$D = 1.223\left(\frac{91.5}{120}\right)^2 = 0.711 \text{ m}$$

Using Equation V-6M, calculate ΔD

$$\Delta D = (1.872+0.075-1.207)\left(\frac{91.5}{120}\right)^2 = 0.43 \text{ m}$$

Select the appropriate chart which is that shown by Figure V-16. Enter the x-axis at the value of ΔD = 0.43 m. Project vertically to the family of D curves. D = 0.711 m will be located approximately two thirds of the way up from the 0.9 m to the 0.6 m sag curve. This will be found to fall approximately 30 percent of the way up between the 120 and the 150 m maximum span values, or about 129 m. It is seen that the reading is at best a close approximation. If a more accurate answer is needed use 129 m as the arbitrary assumed value for the maximum span and calculate a more accurate answer by the method given in Section H of this chapter. A review of the same sample problem calculated by the method shows the result to be 130 m.

The resulting allowable span of the preceding example is a longer span than is commonly used for a roll. The reader should be aware that the same change in configuration would result in shorter allowable spans when higher voltages are used, when reduced stringing sag tensions are used, and when the phase conductors operate at higher temperatures.

PART VI
LINE STAKING

INTRODUCTION

In previous parts of this design manual, the NESC safety rules and other design requirements to which the overhead distribution line should conform are discussed. Design methods to aid in conforming to these requirements have been provided. To ensure that the intent of these safety and design requirements is satisfied, it is necessary that the line be properly staked.

Part VI provides guidance to staking engineers to assist in the proper staking of the lines. This part does not cover every detail of the staking process; however, it provides general guidelines which will assist the staker in designing a line in conformance with the safety and design requirements.

There is more to staking than merely measuring, aligning, and driving pegs at spots that look like good places to set poles. Staking consists of examination of the local conditions, application of the data to those conditions in order to determine the most practical location for the pole, and then selection of the most appropriate construction units to support the line conductors. Thus the staking is an important and final step in the engineering design of the line. The staker need not know every detail necessary to prepare technical design information, but should at least have a concept of how the information is prepared. If the staker is not aware of some of the tolerances "incorporated" into the design criteria and some of the assumptions made in calculating the design criteria, the staker may use the design aids for purposes that are not intended. The staker should also have a basic understanding of construction, construction methods, and operation of distribution lines. Without this basic understanding, the staker may unnecessarily specify units which are difficult to build and to maintain. In addition, the staker needs to be aware of economic consequences of these decisions. Often units have vastly different costs but serve essentially the same purpose. Sometimes the staker must make a compromise concerning ease of operation, ease of construction, and cost of construction.

CHAPTER VI-1
GENERAL PROCEDURES FOR STAKING

A. GENERAL PROCEDURES

In this chapter the general procedures and mechanics for staking a line section are reviewed. Details for performing various staking design functions using staking guide data are covered under other chapters as referenced.

Staking distribution line is basically the determination of conductor span lengths, alignment of poles, selection of proper conductor supports, provision for adequate clearances, and determination of the necessary structure strength for all conductor spans in the line section in a manner that will provide the desired reliability at a reasonable cost.

The staking of the line section is accomplished by the following general procedures:

- The progressive reduction of the length of the line section into smaller length segments until the line section consists of a series of segments with lengths suitable for supporting spans of conductors. The reduction is accomplished by first determining the lengths of those segments limited by control points. These control segments are then divided into appropriate span segments.
- The division of the line section into alignment segments which will permit the longest possible alignments of poles within the limits permitted by the rights-of-way agreements.
- Selection of the proper conductor support assembly required for the type of crossing and line angle, if any, at each pole location.

- Determination of the height of pole necessary for the conductor support assembly to provide the required conductor clearance in the adjacent spans and to prevent uplift of the conductor.
- Determination of the necessary strength of the structure including guy requirements, if any. Identification of pole class and guy and anchor assembly units.
- Recording of determinations on staking sheets.

B. DETERMINING CONTROL POINTS

The determination of control points commences with the final selection of the line route. The first control points established are those where the route obviously must change direction. During both the planning stage and staking, other points will be found which will control the lengths of the intermediate line segments. Some of these control points will affect the exact alignment of the pole centerline while others will not. They may be due to topographic features, man-made objects, and rights-of-way limitations.

Those which may establish pole locations but may not affect alignment include:

- Points required for junction poles or transformers and service taps;
- Abrupt changes in topography;
- Rights-of-way requirements for poles to be adjacent to fence crossings;
- Special clearance problems requiring a pole at, or close to, a crossing.

Those which may require changes in alignment may include:

- Changes in direction of the line;
- Less obvious changes in alignment due to minor changes in direction of roads or fences being paralleled;
- Required minimum horizontal clearances to objects being passed;
- Rights-of-way restrictions which require minor alignment adjustments.

The first step to be taken when actual staking starts is to determine, as accurately as possible, all of the control points that will fix locations of poles. The span-by-span detail staking is then done in segments between these control points. If control points are missed and then found during the detailed staking, it may be necessary to re-stake the line in that particular segment.

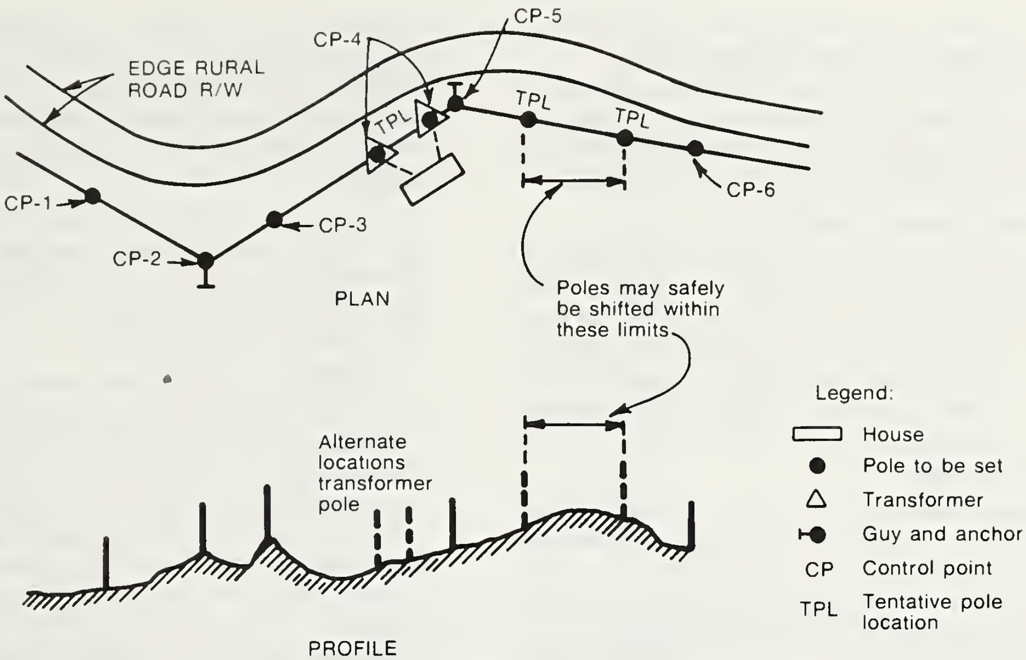
Some of these control points are definitely fixed and others allow some leeway which the staking engineer may use to advantage in obtaining desired span lengths. Field conditions often make it necessary to shift the pole locations in a few spans or perhaps increase the height of an occasional pole in order to obtain the best average span length. Some apparent control points can be shifted to another point and thereby reduce the total number of control points. Figure VI-1 illustrates some of the control points which can be shifted.

Comments concerning the control points on Figure VI-1 follow:

- Point 1: This point is the approximate end of an alignment along a road right-of-way. The option exists of projecting on to Point 2 or angling to Point 3.
- Point 2: This point is the intersection of two straight line sections. It cannot be moved without adding a line angle.
- Point 3: This is a topographic control point. The point does not affect alignment but a pole must be located on line somewhere in the short distance across the knob.
- Point 4: A pole is required for the transformer. A right-of-way restriction states the pole can be either side of the yard, but not in front of the house. Two options exist for the pole location.
- Point 5: Comment same as Point 2.
- Point 6: This point is on the end of an alignment along a straight road. It becomes an angle point if the alignment cannot be projected back to Point 5.

The use of guyed angle structures increases the cost of line construction as well as operating and maintenance expenses and should be avoided whenever possible. Generally, the fewer angles in a line, the more economical it is to build. In most cases, it is desirable to avoid a series of small angles by extending the tangent segments as far as possible. Long span construction usually makes it impractical to follow along sweeping curves on a series of small-angle unguyed poles.

If an alignment angle in the line is so small that a structure placed at the angle point would not require a guy, then the angle should not be



TYPICAL CONTROL POINTS
FIGURE VI-1

considered a control point. In this case the pole need not be placed on the point. Sometimes it is possible to avoid use of a small angle guy by deliberately dividing the angle between two unguyed poles.

C. MEASURING CONTROL SEGMENTS

Establishing control points determines the location of certain poles. Between these points, the staker must select the pole locations that will provide the best line design. The intermediate spans should be as uniform as possible and, if possible, the average length should be some value between the basic design average span and the shorter of either the design ruling span, maximum horizontal span, or basic level ground span.

In suggesting the above limits for selecting average spans, it is assumed, due to topography, the spans will not be even. Approximately as many spans will be longer than the average span as will be shorter.

There are three basic approaches to determine the average span of the segment, any of which may be most appropriate under given circumstances. These are:

- Exact measurement of control segment;
- Approximate determination of average span;
- Assume that average span equals or exceeds basic design average span.

1. Exact measurement of control segment:

The distance between control points is measured to the same degree of accuracy as required for measuring individual design spans. Reference measuring points may be left at regular intervals to minimize the amount of measuring required when measuring actual span lengths.

When the total length has been determined, the average span length is calculated which, if possible, will fall between the limits given above. This average span is used as a basis for designing the individual spans of the segment.

2. Approximate determination of average span:

The segment distance is estimated using the most convenient means available. This might include maps, known land divisions (section lines, quarter-section lines), measuring wheels, and other measuring devices. The accuracy of the measurement should be such that the error of the calculated average span will not be in excess of about 2 meters [6 ft]. If possible, the average span should fall between the basic design average span and the upper limits given above.

3. **Assume that average span equals or exceeds basic design average span:**

The staking of the individual spans proceeds, without measuring or estimating the segment length, using the staking table and basic pole height and class as guides to span lengths.

4. **Comparison of methods:**

The first method is generally best when the segment is short and the third method is best when the segment is very long. When staking between control points using the second and third methods, any appreciable departure from the average span that occurs in the last span must be minimized by readjusting the last several spans.

During the detailed staking, if one of these latter two methods has been used to determine the average span, it may be practical, at some point, to make an exact measurement of the remaining distance to the control point and to adjust the average span for the remaining portion of the segment.

D. MEASURING SPANS

It is normal practice in recording span measurements to round the measurement to the closest link of the measuring chain. For chains commonly used for staking, the link length is 0.2 meters for a 20-meter chain and one foot for a 100-foot chain. Thus, the tolerance of recording is 0.1 meter or 0.5 feet.

When sagging conductors, the total accuracy of span measurement is of concern. For small measurement errors, the percent sag error due to span measurement error will be approximately twice the percent error in measuring the span. It is desirable to limit the sag error due to this cause to approximately one percent. Thus, the span measurement error should be limited to plus or minus 0.5 percent. Therefore, each chain measurement within the span should also be limited to 0.5 percent error. From a practical standpoint, since not all errors will accumulate in the same direction, the desired accuracy will generally be achieved if each individual chaining measurement is measured to the closest link.

The degree of measuring accuracy will vary with the method of measurement. If a 100-meter span could be level measured with a 100-meter chain, measuring to the closest link would provide a maximum error of 0.1 percent. Other measuring methods may produce errors in excess of 0.5 percent. Percentage errors up to 1.0 percent may be permissible for general span measurement provided additional ground clearance tolerance is provided in the staking tables. However, the span in which the conductor sagging is measured should be measured accurately with an error not in excess of 0.5 percent.

It is common practice to locate the pole so the span length is to the closest one meter or closest five feet. This simplifies calculations and use of data tables, but is not indicative of the required accuracy of measurement.

Design computations are based on the level horizontal distances between poles; therefore, the measurements theoretically should be level. From a practical standpoint, it is not necessary to level-chain until the slope is such that the measured error would be greater than the accuracy indicated above. It is recommended that level-chaining be used or the measurement corrected for slope when the slope exceeds approximately 8 percent (8 vertical units per 100 horizontal units), or a vertical deflection angle of 5°. At this slope, the correction will add one link of the chain to the measurement when rounding off the measurement to the closest link of a 20-meter or 100-foot chain. Slope angles can be quickly measured by an Abney hand level, a hand-held instrument for measuring vertical angles.

When slope chaining, the slope measurement should be adjusted to represent the correct horizontal distance. For example, when slope chaining with a 20-meter chain, the slope distance is adjusted so that the horizontal distance equals 20 meters. The length to be added to the measured slope distance can be found by multiplying the measured distance by the correction factor F_S which is determined from the vertical deflection angle (θ) of the slope.

$$F_S = (\tan\theta)(\tan(\theta/2)) = (\sec\theta) - 1 \qquad \text{EQ VI-1A}$$

Table VI-1 provides values for F_S for a range of slopes measured by both slope deflection angle and percent slope.

The use of the table is illustrated by the two following examples.

- **Example 1.**

The staker is chaining with a 20-meter chain. By use of an Abney hand level the slope angle is found to be 8°. What correction should be added to each chain length?

Correction = 0.0098 × 20 = 0.2 meter

TABLE VI-1

SLOPE MEASUREMENT CORRECTION FACTORS

Slope Angle θ	Correction Factor F_s	Percent Slope	Correction Factor F_s
3°[1]	0.0014	6%[1]	0.0018
4°	0.0024	7%	0.0024
5°[2]	0.0038	8%[2]	0.0032
6°	0.0055	10%	0.0050
7°	0.0075	12%	0.0072
8°	0.0098	14%	0.0098
9°	0.0125	16%	0.0127
10°	0.0154	18%	0.0161
11°	0.0187	20%	0.0198
12°	0.0223	22%	0.0239

[1]Correction not required

[2]Note that for slopes in excess of 5° or 8% the lack of correction could result in an error larger than that previously recommended for spans of 100 mm [300 ft]. It should be assumed that there will be some measuring error in addition to the slope error.

- **Example 2.**

The staker's eye level is 5.5 feet. Standing on a slope, the staker sights with a hand level to a point on the ground surface, level measures the distance to the point, and finds the distance to be 30.5 feet. What is the percent slope and what correction is needed for a 100-foot chain?

% Slope = (5.5 ÷ 30.5) × 100 = 18%
Correction = 0.0161 × 100 = 1.6 feet

E. MEASURING CONDUCTOR CROSSINGS

The measurement of heights of existing conductors which are to be crossed over or under requires more expertise than any other measurements made by the staker. Essentially all other measurements are made to fixed objects and the clearance is determined at a fixed condition of conductor sag. In conductor crossings, the positions of both conductors are variables and it is probable, at the time of measurement, the existing conductor will not be at the temperature at which the clearance must be determined.

The precise determination of the position of the conductor being crossed at the specified sag conditions cannot be made in the field and the field measurements required to make such determinations are intricate. Usually it is more practical to provide a liberal design tolerance and avoid the exact determination.

If a precise determination is necessary, the following data is required:

- Exact relative elevation of all conductor supports involved;
- Exact horizontal span lengths of all conductors;
- Type and size of conductors;
- Elevation of existing conductors at point of crossing;
- Conductor sag and temperature at the time of measurement.

The cost of collecting this data and the subsequent computer calculations will generally cost more than using the next longer length of pole for the crossing.

As a minimum, the data collected for a crossing should include:

- Height of existing conductors;
- Temperature at time of measurement;
- Distance from the crossing to supporting poles.

A safe clearance tolerance that can be safely determined in the field assumes that the existing conductor being crossed over will have no sag. This can be determined by measuring the conductor height, measuring the conductor sag by the stopwatch method, and adding the

calculated sag at the point of crossing to the measured conductor height. NESC clearance requirements are then applied to this adjusted height. This method involves the sag of the conductor being crossed as the design and construction tolerance. If the sags are large, judgment must be used in the application. This method is demonstrated by the following example:

- **Problem:**

While staking for a new 24.9/14.4 kV line, it is necessary to cross about midspan an existing 12.5/7.2 kV line of another utility. What height is needed for the neutral conductor to safely clear the existing line?

- **Method of Solution:**

Using an insulated telescoping measuring pole, the height above ground of the top phase conductor of the existing line is found to be 7.3 m (24 ft).

Using the insulated pole again at one of the existing structures, the sag of the existing conductor is checked using the stopwatch method (see Part VII). Three returns of the wave takes 5.7 seconds. Table VII-2 indicates the sag is 1.1 m (43 in). The no-sag elevation of the existing conductor is then 7.3 + 1.1, or 8.4 m (27.6 ft).

It is known that the 1.1 meter differences between the sagged and no-sag condition will provide a liberal construction tolerance, but it is not known exactly how much. In this particular case, it would not be economically practical to determine the exact minimum clearance required. Determine the required vertical clearance from NESC Rule 233.

In making judgments concerning conductor crossings, it should be remembered that the sag of the longer span will generally vary more than the shorter span, and the variations between the conductors will generally be the least when the spans are approximately the same length.

The best method for measuring conductor height is probably the use of a telescoping insulated measuring rod. Another accurate method is by measuring the vertical angle with a surveyor's transit. Less accurate methods can be used, provided liberal clearance tolerances are being used.

F. ALIGNING CONTROL SEGMENTS

For new lines an engineer's transit should generally be used to run the line between control points. The transit may be set up and leveled over one of the control points if one point is visible from the other. By taking a "foresight" on a range rod placed vertically at the other control point, the line is established. A rodperson then proceeds toward the other control point and the transit is used to align the rod at points along the line where poles are to be located. A stake marked with the pole number should be driven on line at each pole location.

If conditions are such that neither control point can be seen from the other, the transit may be set up at some intermediate point where range rods set at each control point are visible. The instrument is set up on a point estimated to be on the line and a backsight taken on one of the control points. The scope is reversed on its horizontal axis and a check is made to determine how far the foresight misses the control point. The transit is then moved about one-half the error and the process is repeated until the transit is "wiggled into" alignment.

There may be some sections of line between control points where it is difficult to line in range rods because of brush, trees, crops, or other obstacles. In such instances, it may be possible to run a parallel line along the edge of a traveled road where visibility is unobstructed. If so, a line may be run as previously described and the pole stake locations determined by offset. If this method is used, care must be exercised to make certain that equal offset distances are measured at right angles to the line established along the road and in the same plane. Otherwise, stakes will be located out of line.

The use of a transit can be avoided if there is another basis of alignment within practical offset measuring distance and the alignment is parallel to the new line. These parallel alignments might include curbs of paved roads, railroad tracks, existing pole lines, and long straight fences. When rights-of-way restrictions tie the alignment of the new line to one of the above, it might be better to offset from the existing alignment. For example, if the terms of an easement state that the poles shall be within three feet of a fence line, which is a half mile long but is found to have a gentle but uniform bow that departs from a straight line by four feet at the midpoint, the practical solution might be to follow the fence bow and take a very small angle on each pole.

Where it is probable there will be difficulty in finding stakes at a later date, the stake location should be indicated by driving a four-foot building lath adjacent to the stake or by providing some other suitable marker. Where the stakes are located on private rights-of-way so as to be invisible from the road because of brush, trees, or crops, a suitable marking ribbon should be provided on the fence so the location of the stake will be indicated from the road. It will also be helpful to place appropriate notes on the staking sheets.

On occasion, it may not be desirable to leave pole location stakes on alignment. This can occur when it is known agricultural operations will destroy the stakes prior to line construction. In such cases, reference or "off-set" stakes may be placed in a protected location. Such stakes must be clearly identified and the offset distance indicated on both the stake and staking sheet.

G. MEASURING AND BISECTING LINE ANGLES

When using the transit to line-in stakes at control points that have angles, the instrument should also be used to measure and bisect the angle and establish the line along which anchors are to be located. A stake should be driven at each anchor rod location.

When a transit is not set up at the control point, the angle can be determined by use of the trigometric functions of an engineering calculator. For example, an alignment is projected past the control point a distance of 10 meters. The perpendicular distance to the other alignment is measured. The second distance divided by the first distance is equal to the tangent of the angle of deflection. Thus, if the perpendicular distance is found to be one meter, the tangent of the angle is 0.1 and the angle will be found to be 5.7°. The bisector of the angle is found by simple geometric bisection. On each alignment a point is marked at equal distances from the control point. The chain is stretched between these two points and measured. The bisector is on a line through the midpoint of this measurement and the control point.

CHAPTER VI-2
STAKING TABLES

A. PURPOSE AND USE OF STAKING TABLES

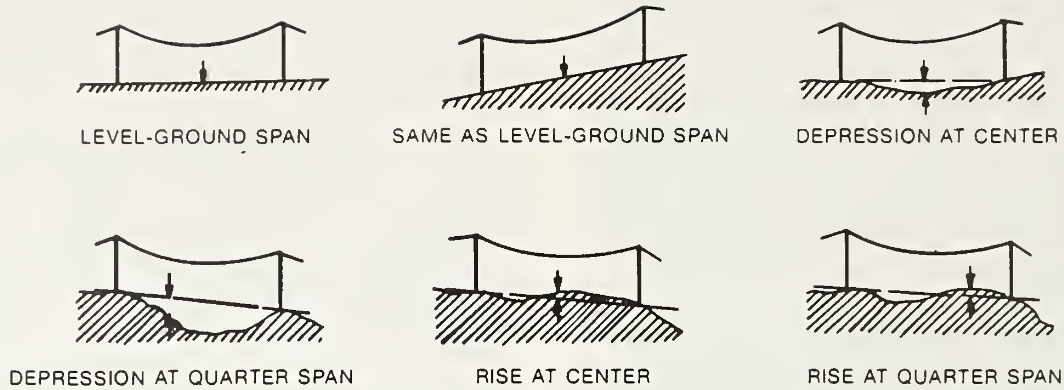
The staking table is a design aid used in field design of overhead distribution lines. It greatly facilitates the time and effort required to stake the lines. It serves the same purpose as plotting a plan and profile of the span and then applying a sag template curve to determine the height of poles necessary to provide the required clearance.

Use of the table is equivalent to taking five profile shots, one at each pole location, one at each quarter span, and one at midspan. The elevations at the three intermediate points are represented as the distance above (rise) or below (depression) a straight line between the ground elevations at the pole locations. Just as with plan and profile design, one of these elevations will control the position of the ground clearance curve and will determine pole heights. Whether the span length can be increased or needs to be decreased also can be determined.

For a specified basic pole, conductor configuration, conductor design, NESC loading district, basic NESC clearance and specified design and construction tolerance, the staking table tabulates maximum permissible span lengths as a function of the ground elevation at midspan. The ground elevation is referenced as a rise or depression from a ground baseline between the ground elevations at the two basic poles. The ground elevation is varied at regular increments between selected values of rise and depression.

For each tabulated span length the table also provides the value of the quarter span rise for the basic pole which would also limit the maximum permissible span to the same value. The uplift factor for the span length is also tabulated. The table also usually provides for the same span lengths, the permissible midspan and quarter span rise values for the next longer pole length.

Thus, the staking table in tabular form relates the conductor elevation to the ground elevation directly below, much in the same manner as is done graphically in spotting structures on plan and profile sheets. This is demonstrated in Figure VI-2 which illustrates typical ground line conditions which are examined in applying the staking table.



TYPICAL GROUND LINE CONDITIONS

FIGURE VI-2

An example of a metric staking table is shown by Table VI-3 in this chapter. Examples of customary staking tables are provided in Appendix C. The method of preparing staking tables is discussed in Chapter V-3 of Part V.

Each staking table is prepared for a specific design ruling span and is based on the specific sag-tension data prepared for that design ruling span. The tables can be used for a range of the actual theoretical ruling spans provided the theoretical ruling span falls within the acceptable range given on the staking table. Upon completion of staking a stringing and sagging section of line, the theoretical ruling span of the section should be calculated and compared to the acceptable range.

If the theoretical ruling span falls outside the range given for the design ruling span, the staking should be adjusted to bring the theoretical ruling span within the range, or the design should be switched to a design ruling span suitable for the "as staked" theoretical ruling span. This may or may not require field adjustments in the staking. The need for adjustments can be determined by making a comparison of critical sag conditions. The sag comparison is made by the use of the following equation:

$$D_c = D_r \left(\frac{S_a}{S_r}\right)^2 \qquad \text{EQ VI-2A}$$

Where:

D_r = Ruling span sag for the original design ruling span

S_r = Original design ruling span

S_a = Proposed alternate design ruling span

D_c = Calculated sag that occurs in a span of length S_a, if the span was sagged using sag data based on design ruling span S_r

D_a = Sag for span S_a, if sagged with data based on design ruling span S_a

Calculate the sag D_c and compare to sag D_a at the span length of the proposed new design ruling span. Sag checks are needed for the minimum sag condition (uplift condition) and for the basic clearance condition. If the sag at the uplift condition has decreased ($D_a < D_c$), there is some possibility of uplift problems. If the basic clearance sag has increased ($D_a > D_c$), there is some possibility of clearance violations. If reasonable design and construction tolerances have been included in the design and staking, usually there will be no problems when shifting to the next closest design ruling span.

The reader is again reminded that staking tables prepared prior to 1977 are probably no longer valid and their use may result in NESC clearance violations.

B. IMPACT OF METRICATION ON STAKING TABLES

During the period of transition from the customary to the metric system of units, it is necessary that the staker understands the basis for the preparation of the staking table being used to stake the line. The current proposed

changes in the dimensions of wood poles for metrication of ANSI 05.1 are sufficient to cause clearance problems if certain combinations of poles and staking tables are used. During the transition period it is contemplated that both metric poles and customary poles may be available and used in construction, sometimes in the same line. Using metric poles on a line staked with tables based on customary dimensioned poles will result in added clearance of approximately 0.3 meters [1.0 ft]. Using customary poles on a line staked with tables based on metric dimensioned poles will result in a shortage of clearance of approximately 0.3 meters [1.0 ft], unless staked with an added design tolerance of that amount.

Metric and customary pole lengths and setting depths are given in Table VI-2. The metric staking table given on Table VI-3 is based on metric length poles with the lengths given by Table VI-2.

C. APPLICATION OF THE STAKING TABLE

The staking table gives a range of permissible maximum span lengths for the span between two identical pole structures, as the midspan ground elevation changes in regular increments from some selected value of rise above level ground to another selected value of depression (negative rise) below level ground.

For the example staking table shown by Table VI-3, the basic structure is an 11 meter pole with a C1 type conductor configuration. The controlling conductor is a 1/0 ACSR neutral conductor. The midspan clearance is based on a 5.5 meter [18 ft] NESC basic other land clearance plus a 0.2 meter design and construction tolerance. The table was prepared in conformance with Chapter V-3 of Part V. The normal final sag at 15°C [60°F] is 1.02 meters taken from the sag-tension table shown in Table IV-4 in Part IV. The design ruling span is 100 meters.

It is seen that the span length for a level ground condition is 116 meters and the spans range from 63 meters for a rise of 1.6 meters to 211 meters for a depression of 4.4 meters.

For the basic pole the table also provides the value of rise or depression at the quarter span points which would permit the same span length. The table also provides the midspan and quarter span rise and depression values that would permit this span length when using the next longer pole length of 12.5 meters. The last column is the uplift factor for this span length which is discussed in the next chapter.

Although the staking table includes data only for spans with matched structures and then only for two lengths of poles, the table can be used for matched structures of other lengths, for poles of

TABLE VI-2

POLE LENGTHS AND SETTING DEPTHS

(Proposed)* Metric Standard Lengths				Customary Standard Lengths			
Pole Length		Setting Depth		Pole Length		Setting Depth	
m	(ft.)	m	(ft.)	ft.	(m)	ft.	(m)
9.5	(31.2)	1.7	(5.6)	30	(9.1)	5.5	(1.68)
11.0	(36.1)	1.8	(5.9)	35	(10.7)	6.0	(1.83)
12.5	(41.0)	1.9	(6.2)	40	(12.2)	6.0	(1.83)
14.0	(45.9)	2.0	(6.6)	45	(13.7)	6.5	(1.98)
15.5	(50.9)	2.2	(7.2)	50	(15.2)	7.0	(2.13)
17.0	(55.8)	2.3	(7.5)	55	(16.6)	7.5	(2.29)

* The metric pole lengths given here are as proposed by the ANSI 05 Committee, for future use in ANSI Standards. They are not yet a part of an approved ANSI Standard.

TABLE VI-3
STAKING TABLE

11.0 Meter Poles				12.5 Meter Poles	
Quarter Point of Span, Meters	Center of Span, Meters	Span Length Meters	Center of Span, Meters	Quarter Point of Span, Meters	Uplift Factor Meters
1.7	1.6	63	3.0	3.1	0.6
1.5	1.4	71	2.8	2.9	0.8
1.4	1.2	79	2.6	2.8	0.9
1.2	1.0	86	2.4	2.6	1.1
1.0	0.8	93	2.2	2.4	1.3
0.9	0.6	99	2.0	2.3	1.5
0.7	0.4	105	1.8	2.1	1.7
0.5	0.2	111	1.6	1.9	1.9
0.4	Level 0.0	116	1.4	1.8	2.1
0.2	-0.2	122	1.2	1.6	2.3
0.1	-0.4	127	1.0	1.5	2.5
-0.1	-0.6	132	0.8	1.3	2.7
-0.3	-0.8	137	0.6	1.1	2.9
-0.4	-1.0	142	0.4	1.0	3.1
-0.6	-1.2	147	0.2	0.8	3.3
-0.8	-1.4	151	Level 0.0	0.6	3.5
-0.9	-1.6	156	-0.2	0.5	3.7
-1.1	-1.8	160	-0.4	0.3	3.9
-1.2	-2.0	165	-0.6	0.2	4.1
-1.4	-2.2	169	-0.8	0.0	4.3
-1.6	-2.4	173	-1.0	-0.2	4.6
-1.7	-2.6	177	-1.2	-0.3	4.8
-1.9	-2.8	181	-1.4	-0.5	5.0
-2.0	-3.0	185	-1.6	-0.6	5.2
-2.2	-3.2	189	-1.8	-0.8	5.4
-2.4	-3.4	193	-2.0	-1.0	5.6
-2.5	-3.6	196	-2.2	-1.1	5.9
-2.7	-3.8	200	-2.4	-1.3	6.1
-2.8	-4.0	204	-2.6	-1.4	6.3
-3.0	-4.2	207	-2.8	-1.6	6.5
-3.2	-4.4	211	-3.0	-1.8	6.8

different lengths in the same span, and for structures with different conductor configurations at the ends of the span.

The following discussion covers the general application of the table together with the techniques used to adapt the table values to these differing conditions The discussion makes use of the example staking table given on Table VI-3. Figure VI-3 illustrates the discussion.

Assume that Pole 1 has already been staked and an 11 meter pole has been selected, based on clearance requirements of the previous span. The staker makes a preliminary selection for the location of Pole 2 at a distance of 120 meters from Pole 1. The staker assumes that an 11 meter pole will be needed at this location, and proceeds to check this assumption by use of the staking table.

When the two poles are the same length, the use of the table is direct. The conductor baseline is a straight line between the controlling conductor supports and in this case, between the neutral supports. All data concerning clearances is referenced to this conductor baseline or another parallel baseline at a known dis-

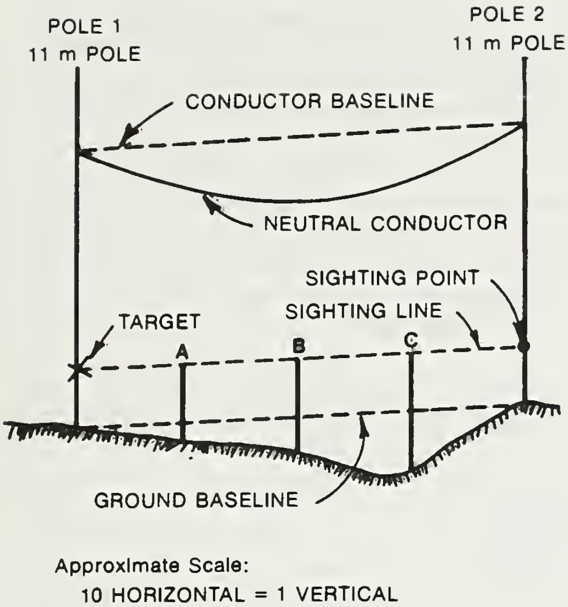


FIGURE VI-3

tance. When the poles are of the same height, a reference line between the ground elevations at the two poles is parallel to the conductor baseline and is used as a ground baseline. Ground elevations above the ground baseline are "rises" and elevations below the base are "depressions." Ground elevations that fall on the baseline are considered "level" even though the baseline may be a sloped line. Since sighting is usually impractical at ground elevations, a sighting line is established above and parallel to the ground baseline.

The sighting is usually done with the naked eye or through a hand level or scope with cross hairs. Therefore, the sighting line is usually established by the eye level of the staker, and in the example, at an elevation of 1.5 meters.

A range pole or some form of target pole is left at the location of Pole 1 with a marker or target set at 1.5 meters above ground. From the preliminary location for Pole 2, the staker sights back on the target while a rodperson moves along the span with a level rod. Readings are taken at the quarter span and midspan locations. The readings in the example are read as: A = -1.9 meters, B = -2.3 meters, C = -3.1 meters. The sighting elevation is subtracted to obtain the ground line rises and in the example are found to be: A = -0.4 m, B = -0.8 meters, C = -1.6 meters. The negative values of rise indicate depression values.

Referring to the staking table, these values of depression are all found to be in excess of the depression values required for 11 meter poles. Point B is the most restrictive and would permit a span of 137 meters.

The staker now has three options: knowing the pole height is safe, the staker could leave it as is; could stretch the span; or could try for a shorter pole. Looking ahead the staker observes that the next span will probably be even shorter so there is no need to stretch the span. Therefore, the staker should decide to try a shorter pole. Figure VI-4 helps illustrate this adaption of the staking table.

In this example the two poles are no longer of the same height and the proposed height of 9.5 meters for Pole 2 is not included in the table. It was stated earlier that the reference baselines had to be parallel to the conductor baseline. Obviously, a line connecting the ground elevations of two poles of different heights will not be parallel to the conductor baseline. Therefore, the ground baseline and sighting line must be adjusted. The staker cannot easily change eye level so the adjusting is done at the target end of the span. A quick look at Figure VI-3 and Figure VI-4, shows that if Pole 1 (target pole) is longer than Pole 2 (sighting pole) the target must be raised. If Pole 1 had been shorter than Pole 2,

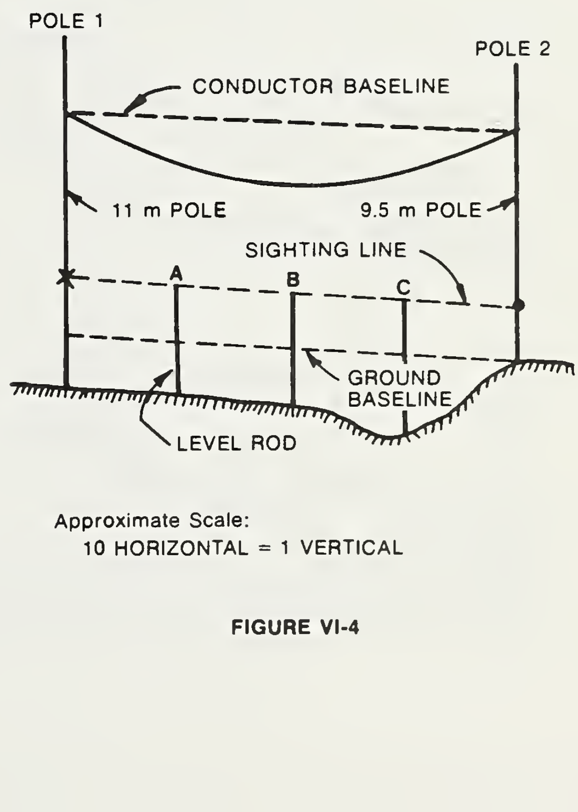


FIGURE VI-4

target would have been lowered. The amount the target is moved is the difference in height above ground of the two poles. This difference is determined from Table VI-4 and is found to be 1.4 meters (9.2 - 7.8). The target at Pole 1 is reset to 2.9 meters above ground (1.5 + 1.4).

The reading of span elevations is repeated and the differences between the readings and sighting elevation (not target elevation) are found to be: A = -1.4 meters, B = -1.4 meters, C = -2.0 meters. One additional problem remains. Since the sighting was done at a 9.5 meter pole, to check the depression values, it is necessary to adjust the table values to those for a 9.5 meter pole. Again referring to Table VI-4, the difference in height above ground of 9.5 and 11 meter poles is found to be 1.4 meters. This is less clearance, and therefore increases the permissible depression. For a 120 meter span the adjusted midspan depression is -1.6 meters for a 9.5 meter pole. The quarter span value is -1.2 meters. The most restrictive span point is found to be at midspan with 0.2 meters more tolerance than required. Therefore, a 9.5 meter pole can be used.

The preceding example has demonstrated the direct application of the staking table as well as two adaptions that permit its use with any combination of pole lengths. A change in conductor configuration is a variation of the problem encountered for two different pole lengths. If the controlling conductor is raised or lowered at the target end of the span, the target is raised or lowered accordingly.

The table can be used for different line-to-ground clearances by adjusting the rise as was done for a change in pole height. If the clearance change is an increase (more restrictive), increase the depression; if a decrease, increase the rise values of the table.

These adaptions are valid so long as the basis for sag increase remains the same. For example, in the heavy and light loading districts the sag increase for spans longer than the basic span is greater for railroad crossings than "other lands" crossings. To use the staking table for railroad crossings the difference in sag increase as well as the difference in basic clearance would have to be considered.

D. PRACTICAL APPLICATION OF STAKING TABLES

In the preceding section, quite accurate methods of measuring ground rise or depression were used to demonstrate the application of the staking table. Such accurate methods of measuring are time consuming and in actual practice are avoided when high accuracy is not needed.

TABLE VI-4

POLE HEIGHT ABOVE GROUND

Metric Poles*		Customary Poles	
Pole Length m	Pole Height m	Pole Length ft.	Pole Height ft.
9.5	7.8	30	24.5
11.0	9.2	35	29.0
12.5	10.6	40	34.0
14.0	12.0	45	38.5
15.5	13.3	50	43.0
17.0	14.7	55	47.5

* The metric pole lengths given here, are as proposed by the ANSI 05 Committee, for future use in ANSI Standards. They are not yet a part of an approved ANSI Standard.

Under actual staking conditions there are many design factors which limit span lengths. Only a small percentage of spans will be limited by the maximum span based on ground clearance. Most spans will therefore have some value of clearance in excess of the minimum required ground clearance. The experienced staker uses this excess clearance as a staking measurement tolerance. As the magnitude of the excess clearance increases, the accuracy required for measurement of ground rise or depression can be decreased.

At each span the staker makes a judgment as to the difference between the required clearance indicated by the staking table and the clearance provided by the actual terrain. The staker then uses the quickest means of measuring that is appropriate for the estimated tolerance. If the measurement indicates that the tolerance is less than anticipated, the rise should be remeasured with a more accurate method. In many cases it will be obvious that no measurement will be necessary.

The inexperienced staker should use reasonably accurate methods of measurement until skill is achieved in making such judgments.

CHAPTER VI-3
CONDUCTOR UPLIFT

A. DESIGNING TO AVOID CONDUCTOR UPLIFT

When staking the lines over rough or rolling terrain, some poles will be located on or near the tops of rises while other poles will have to be located in depressions. When a pole is located in a way that its top may be lower than a straight line between the tops of the two adjacent poles, a check should be made to determine if the conductors will cause an uplift condition at the point of attachment to the pole in question. The uplift condition on rolling ground is illustrated by Figure VI-5.

Uplift can be described as a condition where the conductors exert an upward force on the components of the supporting structure. Uplift is most prevalent and the lifting force most severe at minimum operating temperatures when the contraction of the conductor materials causes minimum sags. The most common damage is the breaking of tie wires permitting the conductor to swing free of the structure.

Uplift problems are one of the most frequently found staking errors, probably because during staking it is one of the least obvious of the staking problems. Also, it has not been common practice to include a design and construction tolerance in the determination of uplift.

The staking aid commonly used to check and to correct uplift is the "uplift factor" which is usually included as a part of the staking table. The uplift factor method of checking uplift is described in detail following under the heading "B. Uplift Factor Method." The method is a relatively simple way to check for uplift for the center pole of three adjacent poles.

The uplift problem becomes more complex when there are two or more poles located in a depression between two highpoints such as might occur when crossing a deep valley. When such is the case a sequence of uplift checks is required when using the uplift factor method. The process can be tedious and prone to error.

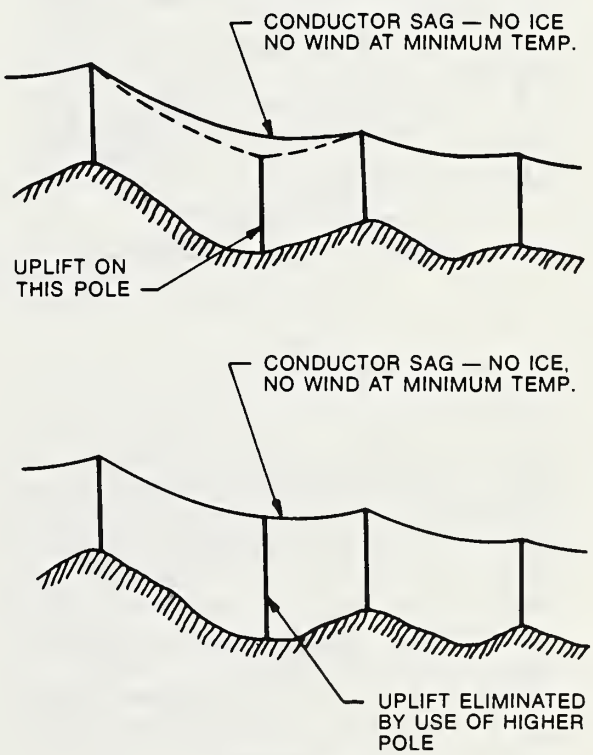


FIGURE VI-5

When the terrain is very rough, it is sometimes desirable to use a surveyors transit or level and to plot a profile. The conductor attachment heights (pole lengths) and locations can then be determined with a conductor sag template. Uplift conditions can be checked with the minimum sag curve of the template. Procedures for preparing plan and profile, preparing templates, and spotting structures is discussed in REA Bulletin 62-1, Design Manual for High Voltage Transmission Lines.

B. UPLIFT FACTOR METHOD

The uplift factor method for checking and correcting for uplift on the center pole of three adjacent poles is actually a variation of the staking table method for checking clearance. What is desired in this particular case is to assure that there will be no clearance between the conductor and the center structure. The uplift method checks the minimum sag condition between the first and third pole structures as shown by Figure VI-6. The problem is to. determine whether the sag from Pole 1 to Pole 3 will fall above or below the conductor attachment at the center pole.

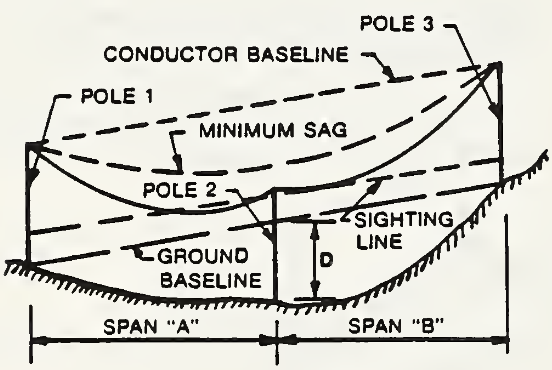


FIGURE VI-6

The conductor baseline, ground baseline, and sighting line are established as discussed under the staking table method except between Poles 1 and 3. If Poles 1 and 3 are different lengths, the ground baseline and sighting line are adjusted parallel to the conductor baseline as discussed in the staking table method. The sighting is done from the unadjusted pole location. The depression is measured at the proposed location for the center pole, and the difference between the sighting line and ground baseline subtracted from the reading to provide the amount of depression below the adjusted ground baseline.

The center pole is assumed to be the same length as the pole from which the sighting was done. If the minimum sag value between Poles 1 and 3 is greater than the depression value D at the center pole location, there will be no uplift. If the sag value is less than the value for D, there will be uplift at minimum sag conditions. The minimum sag value at the center pole is found by use of the uplift factor column on the staking table.

C. DETERMINING UPLIFT SAG

The uplift factor column on the staking table represents values which are the minimum midspan sags for spans twice the length of the span with which the value is associated on the table. If the center pole is at midspan, Spans A and B are equal. Find the uplift factor for a span the length of Span A on the staking table. The uplift factor is the minimum sag value at midspan. Usually interpolation is required to find the value. If the center pole is not at midspan, find the uplift factors for both Spans A and B and average the two values to find the uplift factor at the center pole.

If an uplift factor table is not available, the uplift factor can be calculated provided the ruling span value for the minimum initial sag is known.

$$D_{uf} = 4\, D_{ur} \left(\frac{S_u}{S_r}\right)^2 \qquad \text{EQ VI-3A}$$

Where:

D_{uf} = The uplift factor for Span S_u
S_u = Span length A or B
S_r = Design ruling span
D_{ur} = Minimum initial ruling span sag

The factor is calculated for Spans A and B and averaged as before. The average value is assumed as being the uplift sag at the center pole.

D. UPLIFT DESIGN TOLERANCE

Because of the prevalence of uplift problems, it is suggested that a design and construction tolerance be included in the determination of the uplift at the center pole. The simplest method is to increase the depression value by the amount desired for tolerance. The tolerance value should be based on system experience. It

is recommended that the value be not less than 0.3 meters [1.0 ft].

E. CORRECTING FOR UPLIFT

If uplift is found to occur, the obvious solution is to increase the length of the center pole as required to eliminate uplift. Remember that the net increase is the difference in height above ground as given in Table VI-4. If the amount of uplift is small, the correction can sometimes be accomplished by relocating the center pole or one of the adjacent poles.

F. UPLIFT CALCULATION PROCEDURE

The uplift problem is a comparison problem which compares the elevation of the conductor attachment of the center pole to the elevation of the sag at that point. If it is assumed that the three poles are of the same height, the conductor baseline can be lowered and superimposed on the ground baseline. The sag curve is also lowered and intersects the ground line at the location of Poles 1 and 3. Now the ground line at the center pole represents the location of the conductor attachment point with respect to the sag curve. The problem is to find whether this point is above the sag curve (no uplift) or below (uplift) and how much the pole height must be raised to eliminate uplift. The sag point and attachment points are both depressed below the ground baseline and are therefore negative numbers. In the problem all factors which increase the depression of the pole are negative values, and those which decrease the depression are positive values.

The arithmetic is demonstrated by the following example problem. Referring to Figure VI-6, assume Span A to be 116 meters and Span B to be 132 meters. Assume the pole lengths to be 11 meters. The sighting elevation of the staker is 1.5 meters. The staker reads the depression at the center pole to be 6.3 meters. Check and correct for uplift using the example staking table shown by Table VI-3.

- Step 1 — Determine depression of pole below the ground baseline. Subtract the sighting elevation from the elevation reading. The actual depression is found to be (-6.3) + 1.5 = (-4.8) meters.
- Step 2 — Add a design tolerance of (-0.3) meter to the depression. The adjusted depression is found to be (-4.8) + (-0.3) = (-5.1) meters. Omit this step if the tolerance is included in the uplift factor given in the staking table.
- Step 3 — Calculate uplift sag. Uplift factor for Span A is found to be 2.1 meters and for Span B, 2.7 meters. The average sag is therefore (-2.4) meters.
- Step 4 — Check for uplift. Subtract the average sag from the adjusted pole depression. (-5.1) - (-2.4) = -2.7 meters. Thus the pole height must be increased at least 2.7 meters.
- Step 5 — Select new pole height, refer to Table VI-4. It is found that a 14 meter pole will have 2.8 meters greater height above ground than an 11 meter pole.
- Conclusion — Use a 14 meter pole for Pole 2.

CHAPTER VI-4
SPAN LIMITATIONS FOR TANGENT STRUCTURES

A. STAKING WITH SPAN LIMITATIONS

The variable costs of constructing a rural distribution line are closely related to the number of structures required to build the line. The ability of the staker to design the line with the fewest practical number of structures is handicapped by control points and numerous span limitations. The latitude which the staker has to optimize the design of the line is essentially restricted to the tangent structure spans in the sections between control points.

The staker must know and understand the nature of the limitations. Some, such as the staking table and pole strength table maximum spans, are limitations with options. The ability to select the best spots to use poles of greater length and strength in order to optimize span lengths or to avoid being trapped into using short spans elsewhere is a test of skill of the good staker.

B. THE POLE STRENGTH TABLE

The pole strength table is a span limit table which gives the maximum allowable span for a series of pole heights and classes. Thus if the span limit is too restrictive for the basic class

pole, the limitation can be relaxed by selecting a stronger class pole.

Table VI-5 is a partial example of a pole strength table which shows the strength for a Grade C pole. A complete table would also include span data for Grade B and Grade C crossings. The preparation of pole strength tables is discussed in Chapter V-4 of Part V.

TABLE VI-5

MAXIMUM ALLOWABLE SPAN GRADE C

Pole Height (ft.)	Pole Class (ft.)			
	4	5	6	7
30	559	451	337	280
35	557	432	347	274
40	565	445	343	---
45	555	441	344	---
50	551	441	---	---

Phase Conductor: 4/0 ACSR

Neutral Conductor: 2/0 ACSR

Loading District: Heavy

12.5/7.2 kV, 3-Phase Line

C1-2 Type Construction

The table is prepared for a specific number, size and type of conductor, pole top assembly configuration, species of wood, and NESC loading district. Identification of these parameters should be included with the table. The example table is in customary units and based on the 1979 Edition of ANSI 05.1.

The allowable span data of the staking table may be found in either of two different forms, these being the horizontal span (wind span), or the sum-of-adjacent spans (SAS). The choice of presentation should also be identified on the table so that the staker is aware of which procedure should be used in applying the table. In the first instance the staker averages the two adjacent spans and in the second, the two spans are added before applying the table. The example table is a wind span table.

Reading the table is simple. The real application of the table is to use it together with the staking table to optimize spans. The new staker also needs to learn where to switch to the Grade B and Grade C crossing span data. There are other reasons at some locations for increasing the strength or class of the pole. It is suggested that the pole strength be increased at service and primary tap poles. This is discussed in more detail in Chapter VI-6 under the heading "Service Guys." The pole class should also generally be increased at transformer, recloser, and other poles which support heavy equipment and are frequently climbed.

The table can also be used to determine the pole class and span limitation for a small unguyed angle pole, provided a span reduction factor is included with the table. Such a factor may be presented in one of several forms. One type form presents the factor as the number of units (meters or feet) that the span should be reduced for each added angle increment (degree, 15 minutes, etc). Another form is the span reduction factor constant K_t which gives the span reduction when multiplied by the sine of one-half the line angle. An example is given in Chapter V-4 of Part V.

C. MISCELLANEOUS TANGENT SPAN LIMITATIONS

The majority of the remainder of tangent span limitations are of the fixed type. Most will be used infrequently. Different limitations may be the controlling factors under different conditions. It is suggested that these be tabulated and located together and at one place in the staking design guide for easy reference by the staker. A list of a number of such limitations follows. Some listed will not be applicable to all designs or all local areas. For some designs and local areas there will be other limitations which have not been listed.

- Maximum span based on conductor separation: gives maximum spans for all combinations commonly encountered on the line and identifies the basic configuration at each of the two poles, e.g., (C1-C1) (C1-C3) (C3-C3), etc. If the design may be used for some lines subject to high operating temperatures and some that are not, the table should give two sets of values: one for normal temperature and one for the high temperature condition.
- Maximum wind span based on pin strength: gives the maximum no-angle span limit for the commonly used tangent structures.
- Maximum vertical span: gives maximum vertical span based on crossarm strength for

basic structure and other tangent structures that are commonly used in the line.

- Maximum span based on galloping conductors: use where applicable. Usually this is the span length where the Lissajous ellipses just touch as defined in REA Bulletin 62-1. This limitation is usually provided only for the basic tangent structure configuration.
- Maximum spans permitted for special crossings, e.g., railroads, interstate highways, etc.

CHAPTER VI-5
LIMITATIONS AT ANGLES AND DEAD ENDS

A. STAKING ANGLE AND DEAD-END STRUCTURES

Limitations imposed on angle structures may have some impact on the adjacent spans, but to a greater degree they limit the magnitude of the angle that can be supported by the structure.

The guying of angle and dead-end structures is discussed in Chapter VI-6. The selection of these structures together with the guying design will require considerable effort and skill on the part of the staker.

B. SMALL ANGLE CONSTRUCTION ASSEMBLY LIMITS

Pin type and post type insulator assemblies are most commonly used to support conductors on tangent line structures. They are also used for small angles, and by doubling the assemblies the permissible angle can be increased. The angle may be limited by the crossarm insulator assembly, the pole top insulator assembly, and sometimes by the neutral support assembly.

For a given construction assembly, conductor size and design tension, the permissible angle is a function of both the conductor tension and wind span. As an aid to the staker, a "pin strength table" is usually provided as a part of the staking design guide. This is a misnomer as the table may also include data concerning post type insulator assemblies and tension insulator assemblies such as used on the REA type C3.

Table VI-6 shows an example "pin strength table." The use of the table is simple. The limitations for each construction assembly can be read directly from the table. For each assembly unit listed, maximum angles are given for a series of wind spans (one-half of the sum of the adjacent spans). As the span increases the angle decreases. Straight line interpolation is used to determine values of wind span or angles which fall between tabulated values.

The computation procedures in preparing the table are found in Chapter III-6 and can be used in computations for special construction units not included in the table.

TABLE VI-6
CROSSARM PIN STRENGTH
GRADE C

Assembly Type	Pin Strength, N	Span Length, M							
		40	55	70	85	100	115	130	145
		Allowable Line Angles°							
C1	2224	6	5	5	4	3	2	1	---
C1-2	4448	16	15	14	13	12	11	10	9
C2-2	8896	35	34	33	32	31	30	29	28

Conductor: 3/0 ACSR

Loading District: Heavy

Design Tension: 11.875 kN

Small angle design becomes more troublesome as the conductor sizes and tensions increase. Angles should be avoided wherever possible.

Where necessary, select control points with adequate guy lead space. When approaching a small angle location the staker should control the spans to minimize the wind span on the small angle structure.

C. LARGE ANGLE AND DEAD-END CONSTRUCTION ASSEMBLY LIMITS

Dead-end type construction assemblies are used for single dead ends, double dead ends, and for large angles. Large angle assemblies usually consist of two single dead-end assemblies and like single dead ends must be capable of holding the entire tension design load in the direction the load is applied.

Double dead-end assemblies are normally tangent line structures used to isolate line sections, change conductor size, control uplift, change conductor design tension, etc. Double dead-end structures need only support the maximum difference in conductor tension between the two line sections. However, all components of the structure which carry the conductor tensions through the structure must be capable of supporting the entire conductor design tension. The insulator dead-end assemblies carry the entire tension load.

The staker should be aware that for large and extra large conductor sizes, the strength of the dead-end assemblies is often the controling element in the selection of the conductor design tension. The design tension is based on use of a specified dead-end insulator assembly. Therefore any special structure used must also include dead-end assemblies of that or greater strength.

Except for tangent double dead-end construction assemblies, vertical conductor configurations such as REA type C5, with the dead-end insulator assemblies installed directly on the pole, are preferred. There will be situations where it may be necessary to dead-end on arms. Remember that with standard conductor spacing, even with triple arms, that No. 2 (6/1) ACSR is the strongest conductor that can be dead-ended on an arm assembly without reducing the conductor design tension below 50 percent of the ultimate strength. For all larger conductors bridle guying of the arms (REA guy assembly type E5-1) or the designing of special conductor supports is required. Discussion concerning horizontal strengths of arm members is given in Chapter III-6.

Where the large conductor configuration needs to be horizontal at a junction pole it is sometimes more practical to carry the conductor on through the junction structure and dead-end the conductor vertically on the adjacent structure.

CHAPTER VI-6
GUYING AND ANCHORING

A. GUYING DESIGN

The percentage of line structures which are guyed structures is relatively small. However, from the standpoint of line strength, they are the most important. When a dead-end or large angle structure goes down, the line is out of service, and the replacement time is longer than for tangent structures. When they go down in an ice or wind storm, they are also very apt to cause failure of several adjacent tangent structures.

The guyed structures are usually the most difficult to design and stake, generally because the theoretically best guying design cannot be adapted to local guyed structure locations. The complexity of the guying problem is aptly put in perspective by Murphy's law for distribution line design which states, "The more complicated the guying needs to be so the pole won't fall, the greater will be the probability there won't be any place to guy at all."

It would be next to impossible to anticipate and place in the staking design guide all of the variable guying designs that may be required in designing a large conductor line. The staker will probably have to employ the guying design equations for field design more often than any other structure design computation procedure. While guying guide tables are convenient to have, it is also necessary to include in the staking design guide the data required for calculating guying design. The staker should be familiar with the guying design procedures given in Chapter V-6 of Part V.

B. GRADE OF CONSTRUCTION OF GUYS

Since guys and anchors are an integral part of a supporting structure, the grade of construction of the guy should be the same as required for the structure. The structure should be of the grade of construction required for the highest grade conductor supported or attached to the pole. Thus, if the structure supports a Grade B conductor, all guys attached to the structure should be Grade B even though the guy is placed on the structure to support a Grade N, Grade C, or Grade D conductor.

If a distribution circuit (or communication line) is underbuilt on a transmission circuit pole line, the guys and anchors that support the distribution circuit should meet the strength requirement of the transmission line. Refer to REA Bulletin 62-1, Design Manual for High Voltage Transmission Lines, for strength requirements for REA-financed transmission lines.

C. USE OF GUY LEAD TABLES

Guy lead tables or charts are prepared to give the number and size of guys and anchors, and minimum leads for various loads. Most tables give values for 1:1 slope guy leads and in addition give minimum permissible leads for one or more type of guy assemblies. Minimum leads are not recommended leads. For most guys, a 1:1 lead is recommended, if at all possible. Tables should be referred to for minimum leads to ascertain that the lead length available is at least minimum. Always use the longest lead possible that does not exceed a 1:1 slope. If the available lead does not equal the value on the table, additional guys and/or anchors or guys and anchors with higher strength should be utilized.

When guying requirements are not covered by the guy lead table, the guying can be determined using calculation methods given in Chapter V-6 of Part V.

D. ANGLE GUYING

It is important to place bisector guys at an angle structure as near to the true bisector of the line angle as practical. If using a transit to stake line, as is commonly done, the bisector at each angle should be determined as the instrument is set at the angle hub. The anchor stake or stakes are set along this bisector line, as dictated by the number of anchors required for the line angle. Any offset from a true bisector will tend to cause the pole top to lean, and will reduce the holding power of the guy.

E. DEAD-END GUYING

Dead-end structure guys are set in-line with the pull of conductors as nearly as practical. Any offset from straight in-line reduces the holding power of the guy and should be compensated with longer leads or stronger guy-anchor combinations. It is especially important to try for 1:1 guy slopes on dead-end structures.

F. SERVICE AND PRIMARY TAP GUYING

Guys installed at tap lines from a tangent line should be sized to support the entire load on the structure. This includes the sum of the loading in the tap line and the wind load on the tangent structure. The horizontal load on a moderately long span of heavy three-phase line due to a wind perpendicular to the line may be greater than the ultimate strength of the single-phase tap conductors. If possible, the spans adjacent to a structure with a tap line should be shortened to reduce this problem. The guy for a tap should be analyzed for both the strength required with the wind perpendicular to the tap line (at maximum design tension in the tap conductors) and with the wind perpendicular to the tangent line at maximum horizontal loading and the tension in the tap line at the same temperature with no wind. It is not normally necessary to analyze the loading with a diagonal or angular wind applied to both lines.

The guying of services merits study, particularly with the increasing incidence of large conductors on primary lines and large multiplex service conductors. Service guys have the same conditions imposed on them as the dead-end guys at taps as described above. In common practice a multiplex service drop conductor is installed which is off from a transformer pole in a primary line to a meter pole to the side of the primary line.

The service guy at the primary line pole should be designed as described for a dead-end tap guy in the previous section. That is, it should be guyed for the greater of either the longitudinal design tension of the service cable or for the wind span loading on the primary line

plus the longitudinal tension in the service cable with design vertical load but no horizontal wind load. This is more often a problem at service taps than at primary taps because there is more frequently inadequate space for guying. The problem can be alleviated by reducing the span lengths of the primary line adjacent to the service tap pole. The problem can be eliminated by one of the two following design concepts. Dead-end the service cable on a separate service dead-end pole and slack span the service cable to the primary pole. The other method is to design the primary line as though the service tap did not exist (except for necessary height). NESC Rule 261A2g states, "An extra pole inserted in a normal span for the purpose of supporting a service drop may be ignored." When so installed the wind loading on the primary conductors can be assumed to be taken by the normal span poles, and ignored in designing the service tap pole. This latter method is almost a necessity if the service tap is from a primary underbuild below a Grade B transmission line. If the service drop is attached to the transmission pole the service guy should be Grade B and designed to hold the entire wind span load on both the transmission and distribution primary circuits.

The guy at the service end of the service tap is required to hold, as a minimum, the longitudinal design tension of the service cable as defined by NESC for wind perpendicular to the cable. In some cases the maximum tension imposed on the service guy can be greater than this NESC loading. When the wind is parallel to the service guy, there is no wind loading on the service cable. However, when the wind is in the direction of the tap pole, additional tension is imposed on the cable due to flexing of the tap pole caused by the wind span load on that pole. It is extremely difficult to predict the impact of this load. The flexing of the pole absorbs a portion of this load and the remainder is carried by the service cable and service guy. On one hand, the stiffer the pole, the smaller the load carried by the service; on the other hand, the shorter and tighter the service cable is installed, the greater the load carried by the service guy.

Generally, this will not be a problem provided the service is properly guyed to support its own design load. However, for certain combinations it can be a problem. The probability of failure of the service cable or guy can be alleviated by reducing the wind span on the tap pole (avoid long adjacent spans) and by stiffening the tap pole. This can be done by installing a Grade B pole at the tap or increasing the pole by a class above that normally required by the pole strength table.

A similar situation can occur at a primary tap pole. In this case the tap line spans are generally longer and flexing of the tap line poles spreads the loading over several spans of the tap line. For primary tap poles, it is also advisable to stiffen the junction pole by increasing the class, to reduce the flexing of the pole.

G. GUY ATTACHMENTS

In selecting the type of guy assembly for the structure, particular attention should be given to the strength capability of the guy attachment. Not all of the REA assemblies are suitable for the loads imposed by large conductors or have a working load rating equivalent to the higher strength guy strands.

H. COLUMN LOADING

At guyed structures, the staker should verify that the pole is strong enough to withstand column loading limitations as described in Chapter V-6 of Part V. The probability of inadequate column strength increases rapidly as guy leads are shortened from the desired 1:1 slope.

I. ANCHOR SELECTION

The selection and design of anchors for the guyed structure are the least precise elements in the design of an overhead distribution line. Without extensive and costly soil tests the physical and chemical characteristics of the soil in which the anchor is to be placed is difficult to determine. For distribution line design, it is economically more practical to overdesign the anchor than to test soil conditions.

Anchor manufacturers provide data concerning the holding power of anchors in various classes of soil. This data has to be used with caution as the data is based on controlled test conditions in which the physical characteristics of the soil are known and the anchor is installed exactly as specified. The data usually infers that factors of safety need to be applied for local conditions. However, little guidance is provided concerning the application of practical margins of safety. Table VI-7 provides a general description of soils for the classifications used in anchor design.

The NESC does not attempt to specify margins of safety for varying soil conditions. The NESC essentially requires that the anchor be capable of holding the tension loads, including overload capacity factors, imposed on the anchor by the attached guys.

Actually, two strength ratings are needed for anchor design. One rating is required for the mechanical strength of the anchor assembly. The other rating is needed to define the resistance of the assembly to pull out in a particular class of soil.

The first rating is a function of the weakest link in the anchor assembly. The safety factor for this rating should also make provision for deterioration of the mechanical strength to chemical or cathodic corrosion. This deterioration will be a function of both the chemical characteristics of the soil and presence of stray electrical currents in the soil, both of which are very unpredictable.

The second rating is a function of the resisting area of the anchor and the physical nature of the soil. The margin of safety needs to make provision for the variance between the estimated and the actual physical strength of soil, or in other words, errors in judging the soil classification.

For systems of REA borrowers the design problem is simplified by REA designated maximum holding power anchor ratings shown on REA construction drawings for anchor assemblies. These ratings respond to both rating requirements and include margins of safety which will generally prove adequate if selected with good judgment and installed correctly.

The REA designated maximum holding power rating for anchors is the maximum permissible load which may be transferred to the anchor rod from the guy assemblies including the applicable overload capacity factor. As such, it represents a rating of the mechanical strength. The rating is also coordinated to represent the maximum permissible holding power of average soil conditions (class 5 soil).

When the anchor is used in poorer soils the holding power of the anchor should be derated. A suggested guide is to derate by 25 percent in class 6 soil and by 50 percent in class 7 soil. For class 8 soil it is usually necessary to use swamp anchors or power driven screw anchors which can penetrate the poor soil into firmer soil.

The designated maximum holding power of the anchor (or derated maximum holding power for poor soils) should be matched as closely as possible with the sum of the rated breaking strengths of the attached guys. When not matched, the capability of the guy-anchor design will be limited by the guys or the anchor whichever is most restrictive.

TABLE VI-7
SOIL CLASSIFICATION
FOR
ANCHOR DESIGN

Class	Engineering Description
0	Sound hard rock, unweathered
1	Very dense and/or cemented sands; coarse gravel and cobbles
2	Dense fine sand; very hard silts and clays (may be preloaded)
3	Dense clayey sands and gravel; hard silts and clays
4	Medium dense sandy gravel; very stiff to hard silts and clays
5	Medium dense coarse sand and sandy gravels; stiff to very stiff silts and clays
6	Loose to medium dense fine to coarse sand; firm to stiff clays and silts
7	Loose fine sand; alluvium; loess; soft-firm clays; varved clays; fill
8	Peat, organic silts; inundated silts, fly ash

CHAPTER VI-7
SPECIAL CROSSINGS

A. SPECIAL CROSSING REQUIREMENTS

The NESC requires certain increased strength requirements for line supports at crossings. See Part II for discussion of crossing requirements.

Grade B crossings require either dead ends or double supports for conductors. This typically includes A9 and C9 types of construction. For railroads the minimum conductor size is No. 6 copper or larger. A Grade B pole strength table should be used in the selection of the pole class

on either side of the crossing. If poles of sufficient class are not available, guys may be used to provide additional strength.

The NESC requires Grade B construction for all railroad and limited access highway crossings. The legal definition of "limited access highway crossings" may vary from state to state, but in general all interstate highways, divided highways, and all highways posted as "limited access" should be considered Grade B crossings.

Grade B construction is also required by the NESC for the communication conductor crossings of more than one pair unless certain protective devices are provided in which case Grade C construction is permitted. Normal REA sectionalizing recommendations provide the protection provided on the power lines, but a check should be made with the telephone company to see that they have adequate protection on their system.

CHAPTER VI-8
STAKING SHEETS

A. PREPARATION OF STAKING SHEETS

It is the responsibility of the staking engineer to prepare the staking sheets. The staking sheets should provide complete information for construction of the line by either an outside contractor or by the system's own construction force.

The staking sheet information should include a tabulation of construction assembly units showing the items of plant to be used. REA has devised construction assembly units for all major components of a line built to REA specifications. A discussion of REA standard construction assembly units is included in Part III of this design manual. The staking engineer indicates a complete supporting structure makeup when he specifies the type, number, and location of construction units to be used.

A major advantage in having a properly prepared staking sheet is that it becomes a continuing plant operating record once the line has been built. A typical staking sheet should provide the following:

- Detailed location of the line including a sketch;
- The right-of-way clearing and trimming units required;
- Construction assembly units for each location;
- Instructions for construction crews;
- Specific conductor types, sizes, and number in each span;
- Length of each conductor span;
- Ruling span for stringing and sagging the conductors;
- Identification of staking design data used;
- A means of verifying and summarizing the construction used;
- A continuing plant record.

The importance of accurate and complete staking sheets cannot be emphasized too strongly. The successful construction of the line will depend directly upon the manner in which the line has been staked and the staking sheets have been prepared.

B. ELECTRICAL CONSIDERATIONS

The staker should ensure that the electrical design considerations are satisfied for the line being staked. Line equipment insulation levels, lightning protection, sectionalizing, grounding, and transformer selection are some of the items that must be considered. These items must be properly shown on the staking sheet, either by notes or proper construction units. See REA Bulletin 160-1, Engineering and Operations Manual for Rural Electric Systems, and other applicable REA bulletins for more detailed electrical design parameters.

C. FORMAT OF THE STAKING SHEET

There are many types and formats of staking sheets in use for staking rural distribution lines. The sheet format that is best for a particular utility is probably one which has been developed by experience for the particular needs of the system. Usually several types of staking sheets are used by a single utility for different types of construction. These might include:

- New overhead line construction staking sheets;
- New underground line staking sheets;
- Overhead line conversion staking sheets;
- Line retirement sheets;
- Housing subdivision staking sheets;
- New service installation sheets.

The particular format of the sheet is not so important as the content of the sheet. Provisions should be made to tabulate or record the information listed in Section A of this chapter. The tabular format should also be arranged in a manner to aid the memory of the staker.

The sheet material should be durable so that it can be used in the field to record the data as the line is staked.

PART VII
LINE CONSTRUCTION AND INSPECTION

INTRODUCTION

The preceding parts of this design manual have discussed and provided guides for the proper design and staking of lines to provide reliable line construction in conformance with the NESC and other design requirements. To assure the completed line will satisfy these requirements, it is also necessary to control the quality of construction during the building of the line.

Part VII provides guidance to assist construction supervisors and inspectors in the control of quality assurance during installation of lines. This part is not intended to be used as specifications for construction. The purpose is to provide assistance in determining that installation will conform with the construction specifications and intended design criteria.

CHAPTER VII-1
SPECIFICATIONS FOR CONSTRUCTION

A. CONSTRUCTION BY CONTRACT

The contract documents for line construction performed by the contractor will normally include a document such as REA Form 804, Specifications and Drawings for 12.5/7.2 kV Line Construction. Specifications for construction are included in Form 804 and the equivalent REA forms for other voltages.

The construction should be in conformance with these specifications. It is suggested that a preconstruction conference be held and attended by representatives of the owner, contractor, and engineer. The purpose of such a meeting is to assure all parties are aware of the intent of the specifications, the procedures to be used by the contractor to conform to the specifications, and the methods to be used by the inspector to assure conformance.

B. CONSTRUCTION BY COOPERATIVE STAFF

When the line construction is to be performed by the owner's construction crew, formalized contract documents will not be available. However, it is advisable to use the same REA form and specifications for construction as would be used if the construction were to be under contract.

It is just as important to hold a preconstruction conference for this type of construction. The meeting should be attended by the owner's engineer, construction supervisor, and inspector. In this case, it is important to determine all parties are using current editions of forms, codes, special construction drawings, and other design and construction data.

C. REFERENCES FOR USE DURING CONSTRUCTION AND INSPECTION

Refer to the following REA forms for specifications for construction to be used for overhead distribution line projects financed by the Rural Electrification Administration.

- REA Form 804, Specifications and Drawings for 12.5/7.2 kV Line Construction
- REA Form 803, Specifications and Drawings for 24.9/14.4 kV Line Construction
- REA Form 801, Specifications and Drawings for 34.5/19.9 kV Line Construction
- REA Bulletin 43-5, List of Materials

For proper construction and inspection of the lines, the following references should also be available.

- National Electrical Safety Code, ANSI C2, current edition
- Local Electrical Safety Code (Available in some states)
- Staking design guide, basic design criteria, and other construction data prepared for line under construction
- This design manual

CHAPTER VII-2
INSTALLATION OF CONSTRUCTION ASSEMBLY UNITS

A. ASSEMBLY OF CONSTRUCTION UNITS

One of the early activities during construction is the installation of construction assemblies on the poles. For new construction, this is usually done on the ground prior to the erection of the pole structure.

Construction supervisors and inspectors should assure that workers install assembly units in conformance with the construction drawings.

Materials and hardware are required by REA Bulletin 40-6, Construction Methods and Purchase of Materials and Equipment,to be in conformance with REA construction drawings and to be listed in REA Bulletin 43-5, List of Materials. Manufacturers frequently have available similar materials of unequal quality and strength. The strength of assembly units as shown on the construction drawings and discussed in Part III of this design manual, are based on strengths of the materials approved and included in Bulletin 43-5. The assembly will be no stronger than the weakest component. Use of inferior material could be a possible cause for failure at less than design loadings.

B. FRAMING AND CONNECTIONS

In order for the line to meet specifications, field framing of poles must be as required for spacings as dimensioned on the construction drawings. Particular attention will be required for drilling holes as workers start using drawings with metric dimensions.

Bolted connections through wood members should be drawn tight to allow for shrinkage of wood. Bolts should be pulled up so that wood is compressed but not so tight that washers or other metal parts break the wood fibers. Fiber breaks on the surface of the pole increases probability of decay or rot of the wood.

CHAPTER VII-3
POLES

A. SETTING DEPTH

It is important that the poles be set to the proper depth. If poles are set too shallow, the transverse loading limitations will be less than those calculated for a specific height and class of pole. On the other hand, when poles are set too deep, the vertical line-to-ground clearance will be less than the amount indicated on the staking tables.

The setting depth of the pole can be checked by measuring from the horizontal brand mark usually located below the manufacturer's mark. Presently, most distribution poles are marked at 3 m [10 ft] from the butt with tolerance of ±25 mm [1 in].

It is recommended that setting depth tolerances not exceed 1/4 of the staking and construction tolerance used in the staking tables or 75 mm [3 in], whichever is smaller.

B. POLE ALIGNMENT

Tangent poles should be aligned within a tolerance of one-half the width of the pole. The poles should be rotated so the crossarm assemblies are perpendicular to the centerline of the pole line.

C. PLUMBING POLES

Poles should be set so that they are plumb except for angle poles and dead-end poles.

Poles at angles and dead-ends may be raked or leaned away from the resultant conductor tension. It is normal practice to design guyed structures so the pole is plumb when the line is under maximum design loading conditions. Under this condition, the guy is under maximum design tension and the pole is under maximum column loading. The raking of the pole is to provide some tolerance for setting of the anchor and to provide for strain in the guy when fully loaded. A recommended guide for amount of rake is between 25 to 50 mm [1 to 2 inches] of rake for each 3 m [10 ft] of pole length after the conductor is installed at the required stringing tension. The poles should be set for this rake rather than using the guys to pull the rake into the pole.

It is also recommended the rake be placed in small angle, unguyed poles. Until the backfill of the pole is firmly established, the continual small pull on the pole will cause leaning toward the bisector of the angle.

CHAPTER VII-4
GUY AND ANCHOR INSTALLATION

A. ANCHOR INSTALLATION

It is essential anchors be installed at their proper depth. If the anchor eyes are installed below the ground line, the guy wire, which is not as heavily galvanized as the anchor, will rust. The holding power of a conventional expanding anchor, plate anchor, log or other dead-man anchor is dependent upon the volume and weight of earth resisting the pull on the anchor. Therefore, if anchors are set too shallow, their holding power is greatly reduced.

Plate, log, and other dead-man anchors should be installed so the top portion of the anchor rests against undisturbed earth. The hole for expanding anchors should be just large enough in diameter to allow the anchor into the hole. The anchor should then be fully expanded and the hole backfilled and tamped. Power driven screw anchors should be installed in a manner and to the torque value recommended by the manufacturer.

The entire length of the anchor rod should be set in a straight line between the pole attachment and the point where the rod attaches to the anchor. If the rod is out-of-alignment or bent, it will eventually pull into alignment causing a lengthening of the guy-anchor assembly. This is apt to cause a leaning or bending of the pole with a resulting reduction of the holding power of the guyed structure.

B. GUY INSTALLATION

The guy assembly is pulled up snug prior to the installation of the conductor. While the guy should not be used to pull the full amount of rake into the pole, it is permissible to pull a small amount of rake to allow for some "setting" of the anchor assembly as it is first loaded.

The guy and anchor assemblies should be rechecked after a period of loading and readjusted if the anchor has pulled any in reaching a permanent set in the soil. At vertical angle and corner structures, where multiple guy assemblies have been installed, a check should be made to assure the guy tensions are balanced and holding the pole straight rather than causing it to bow. The bowing of poles due to unbalanced guys greatly increases probability of pole failure when heavily loaded during an ice or wind storm.

CHAPTER VII-5
BEHAVIOR OF CONDUCTOR DURING STRINGING

A. NEED FOR KNOWLEDGE OF CONDUCTOR BEHAVIOR

Because of the assumptions and simplifications made in developing the mathematical procedures used for the design of the conductor sag and tension data, it will be found in actual field stringing and sagging operations that conductors will not always perform exactly as predicted by the calculations.

It is important that those responsible for the installation and inspection have some basic understanding of the behavior of conductors under actual construction conditions. This knowledge will be useful in making decisions concerning the selection of stringing sections and the selection of spans to be used for checking the conductor sag. It needs to be known, in certain spans, the sag may be more or less than the calculated value and this may be the result of the calculation method rather than due to a construction error.

Before this chapter is read further, a review should be made of those chapters of Part IV which discuss the design of the conductor.

B. CAUSE OF SAG AND TENSION DESIGN ERRORS

Conductor sag and tension errors which result in low tensions and excessive sags are apt to cause inadequate clearance. Errors which result in high tensions and reduced sags can cause uplift, conductor fatigue failures due to aeolian vibration, and excessive tensions under ice loading.

The principal causes of excessive sag or tension errors include:

- Computation errors when staking or sagging;
- Measuring errors during staking or sagging;
- Faulty measuring devices for measuring dis-

tances, elevations, temperatures, tensions, etc;

- Use of incorrect staking and sagging data;
- Poor judgment in selecting stringing sections and sag check spans;
- Errors in preparation of the staking and sagging data;
- Inadequate control of conductor during installation and sagging operations.

It is obvious that any one of the above could result in unacceptable sag and tension error. Most large errors and the great majority of significant small errors are the result of one or a combination of these causes. When the error is apparent, the cause should be determined and corrected.

The inspector should be aware of another cause of sag and tension error. The calculation methods used for conductor design are not exact methods; therefore, a degree of error exists in the computations. Under most conditions, the degree of error is negligible or insignificant. Under certain unique conditions, it is possible for the degree of error to become significant.

The conductor design computations which are most apt to predict results which differ from the results actually found during conductor stringing and sagging are those concerning sags and tensions in a series of spans being strung and sagged in one operation. The following section discusses those field conditions which may cause the difference in results to be significant.

C. SAG ERRORS INTRODUCED BY RULING SPAN THEORY

Even with the advent of large electronic computers, there is no workable mathematical equation which can exactly describe the behavior of an overhead conductor while being supported in stringing travelers, particularly when the spans are of varying length and differ in elevation. The mathematical procedure used is based on the ruling span theory. When actual field conditions vary considerably from the assumptions upon which the theory is based, the calculated results and actual results of conductor sags can be significant.

The ruling span theory for design of a series of spans, which are to be sagged in one operation, is a valuable tool for the construction of overhead lines. Without it, it would be necessary to sag and clip-in the spans one-at-a-time. The theory does introduce a degree of sag and tension error. While the degree of error is generally negligible, under certain actual field conditions, it can become large enough to become a problem. With some understanding of the problem, good judgment can be used in the selection of stringing sections and sag check spans, so the magnitude of the problem can be minimized.

The conductor sag profiles shown on Figure VII-1 are used to illustrate the discussion of this problem.

Diagram A shows a series of six spans of a stringing section which are to be sagged in one operation. The spans are of varying lengths and the supports are at two different elevations. For simplicity, the spans have been selected so spans S_1 and S_6 are of equal length, S_2 and S_3 are equal and 50 percent greater length than S_1. Spans S_3 and S_5 are equal length and twice S_1.

The ruling span theory assumes if the actual spans of the stringing section are replaced by a series of equal spans of such length that the total length of conductor in the section and the horizontal tension of the section will be unchanged from that of the actual spans. Then the sag characteristics of one of these calculated equal spans can be used to determine the sags of the actual spans in the section.

For this example and using the theoretical ruling span equation, the ruling span (S_r) for Diagram A is found to be 1.658 times the length of span *S1*.

$$S_r = \sqrt{\frac{(1^3+1.5^3+2^3+1.5^3+2^3+1^3)\ S_1{}^3}{(1+1.5+2+1.5+2+1)\ S_1}}$$

$$S_r = 1.658\ S_1$$

Diagram B shows the equivalent theoretical stringing section for the actual stringing section shown in Diagram A. Note that the last span is a partial span. For the last span to be a whole span, the ruling span would have to be equal to the average span. By the mathematical definition of the above equation, this is impossible.

For a given value of tension, the sag (D_r) for the ruling span (S_r) can be determined and the sags for the actual spans calculated by the equation:

$$D_x = D_r \left(\frac{S_x}{S_r}\right)^2$$

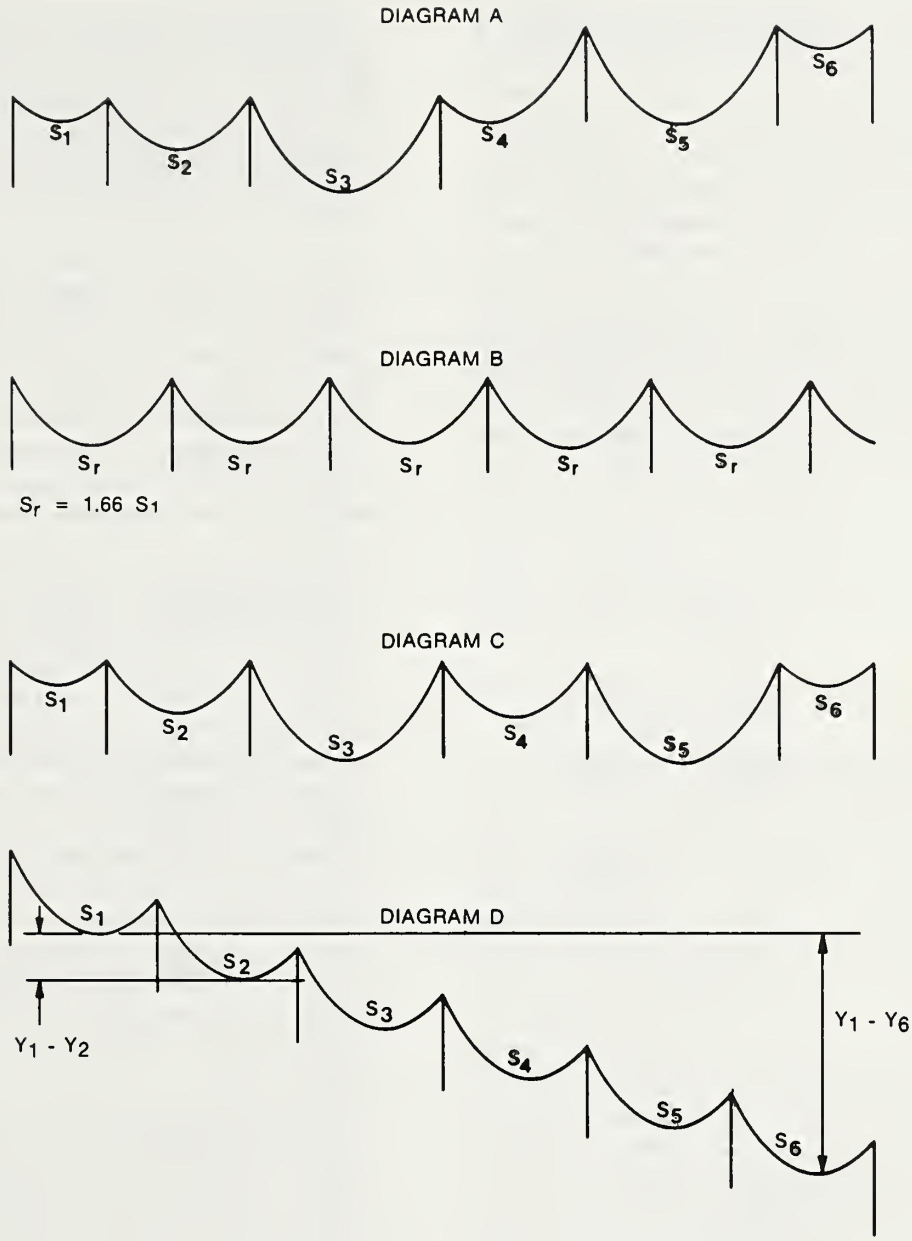


FIGURE VII-1

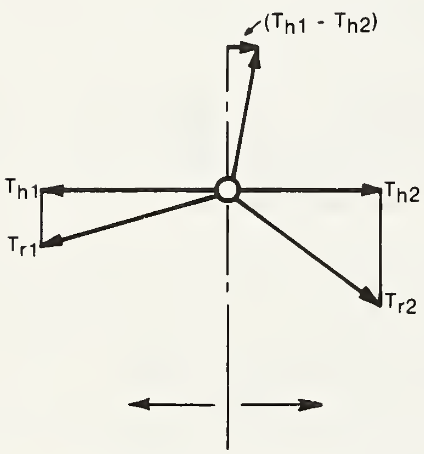
If the stringing section shown by Diagram A is sagged by checking the sag in span S_2, using a sag value derived from the ruling span sag by use of the above equation, then it should also be possible to use the equation to predict the resulting sags in the other spans. However, in this example case, if the resulting sags were to be measured precisely, it will be found the sag in span S_3 is greater than predicted and the other sags are less than predicted.

What is of interest is the cause of these deviations from the calculated values. For the ruling span theory to be completely valid, the following conditions must be satisfied.

- Both supports for each span must be at equal elevations, therefore all supports in the stringing section must be at equal elevations.
- The horizontal component of conductor tension must be constant throughout the stringing section.

It is seen the stringing section of Diagram A violates the first condition above. The impact of this can be examined by assuming a similar case as shown by Diagram C, where the spans are the same length as in Diagram A but all supports are at equal elevations. If the same procedure is followed, it will now be found that sags in spans S_3 and S_5 are greater than predicted and sags in spans S_1 and S_6 are less than predicted.

Since the change made for the second case did not completely solve the problem, a further look needs to be taken concerning the second condition above. The question is whether unequal spans or different elevations of supports can cause changes in horizontal tensions.



$T_{r1} = T_{r2}$

$(T_{h1} - T_{h2}) = W(Y_1 - Y_2)$

W = unit weight of conductor
Y = elevation of low point of sag in a span
T_r = resultant tension of conductor support
T_h = horizontai tension of conductor support

FIGURE VII-2

Figure VII-2 shows the relationship of conductor tension forces at a free rolling support, when the low points of sag in the two adjacent spans are at different elevations. For equilibrium to exist at the support, the resultant tensions T_{r_1} and T_{r_2} must be equal. Therefore, the horizontal tensions T_{h_1} and T_{h_2} cannot be exactly equal. The difference $(T_{h_1}-T_{h_2})$ is equal to the unit weight of the conductor (W) times the difference in elevations of the low points of sag (Y_d) where Y_d equals (Y_1-Y_2). When Y_d is very small, $(T_{h_1}-T_{h_2})$ is negligible and ruling span theory is, for all practical purposes, satisfied. When Y_d is large, an appreciable difference in sag may occur between the actual sag and that predicted by the ruling span theory.

This relationship exists whether the difference in elevation is due to difference in span lengths or due to difference in elevation of supports. In a sense, the conductor rolls into the span with the lowest midspan sag in order to achieve equilibrium. Thus, in the span with the higher midspan sag, the tension increases and sag decreases. In the span with the lower midspan sag, the tension decreases and the sag increases.

D. BEHAVIOR OF CONDUCTOR IN A SERIES OF INCLINED SPANS

The behavior of conductor in an inclined span or in a series of such spans is also related to the above explanation.

Diagram D of Figure VII-1 shows six spans on a slope. The difference in horizontal tension between any two adjacent spans is a function of the difference in elevation between the low points of sag in the two spans. In a series of spans, these differences accumulate. The difference in T_h of the upper and lower spans is therefore a function of the difference in elevation between low points of sag in these two spans. Thus in the example, $(T_{h_1}-T_{h_6})$ is equal to $W(Y_1-Y_6)$.

From the preceding it is seen that while in stringing travelers, the conductor has a natural tendency to run down into inclined spans. It is quite obvious that for a series of spans of equal length and constant slope, regardless of where the sag-check span is located, the sag in each span would progressively increase. Moving up the slope, the average tension increases in each span because, in a sense, the tension in the span is supporting some of the conductor weight in every lower span. If the sloped section of line is sufficiently long, there is a probability of excessive tensions at the top of the slope and inadequate clearances in the lower portions of the slope.

When stringing such sections of line, it is advisable to have sag-check spans at both the lower and upper ends of the slope. There is some possible advantage in pulling the conductor up

to tension from the lower end, leaving some tolerance in the upper span. If there are no clearance problems on the lower slope, the sag can be left low and the conductor clipped in as soon as possible to avoid further running of the conductor. If there are clearance problems in the lower slope areas, several possible corrective actions are available.

If the condition is severe, one of the structures located above the problem area can be dead-ended with supportive guys. Additional tension can then be pulled into the lower spans to bring the conductor sag up to normal conditions. If the condition is less severe, it may be possible to clip in the conductor part way down the slope to stop further running of the conductor in the upper spans and then add additional tension in the lower spans. It must be recognized that on slopes there will always be some degree of longitudinal loading which must be resisted by the flexing of the structures.

When the stringing and sagging construction operation approaches a long inclined slope, it may be advisable to stop the stringing and sagging section near the top of the slope, start another section near the bottom of the slope, and use one or more sections along the slope as needed.

E. IMPACT OF THE LONG SPAN ON SAGGING

The impact of long spans on sagging conductors will usually not be as great as the impact of inclined spans. If three spans are taken so that the center span is twice the adjacent spans and the supports are of equal elevation, the sag of the center span will be approximately four times the sag of the adjacent spans. Therefore, if the sags of the adjacent short spans are equal to one meter, Y_d will be equal to three meters and the difference in the horizontal tension at the supports during stringing would be approximately the weight of three meters of bare cable.

The sagging should not be done using the long span as a sag check span. It would be advisable to check sag on both sides of the long span to assure the conductor pulls up properly on both sides of the long span.

Spans which are so long as to be a problem should be designed as dead-end spans during the staking of the line.

F. BEHAVIOR OF CONDUCTOR IN ROLLING TERRAIN

The topography of rolling terrain is such that most spans will be inclined spans. The spans are usually shorter over the tops of hills and longer across valleys. Therefore, there will exist a combination of the inclined span and the long span problems. Where the difference in elevations between the hilltops and valleys are great, the difference in tension for larger conductors can become appreciable. For example, the vertical force (weight) of 795 kcmil (26/7) ACSR is 16.0 N/m (1.09 lb/ft). For every 100 m (328 ft) difference in elevation of the low points of conductor sag, the horizontal tension will change by 1600 N (360 lb). Such changes in tension can cause very significant deviations from predicted sags and tensions if the stringing sections and sag check spans are not selected to minimize the effect of this change.

G. SAG CHARACTERISTICS OF AN INCLINED SPAN

From the previous discussion, it is quite apparent that for the purpose of sagging in a section of line, the spans selected for the checking of the sag should be as near level as possible. The level span sag can be affected by the adjacent spans which are either long or have steep slopes, and this should be considered when selecting the sag-check span.

While inclined spans should be avoided for sagging of the line section, there will be occasions when it will be necessary to check the sag in an inclined span. It is obvious the length of conductor is greater for an inclined span than for a level span of the same horizontal length. Therefore, there is some question whether the procedures used for checking level spans can also be used for checking inclined spans. The mathematics of skewed parabolas and catenaries are complicated and will not be analyzed here. However, the conclusions are simple. The discussion which follows is based on the mathematics of parabolic conductor spans.

A skewed parabola with a horizontal span of the same length as a level parabola will have the same apparent sag as the level parabola. For a skewed parabolic span the vertical sag is a function of the slope span rather than the horizontal span and is greater than the vertical sag of a level parabolic span with the same length of horizontal span. The apparent sag of the in-

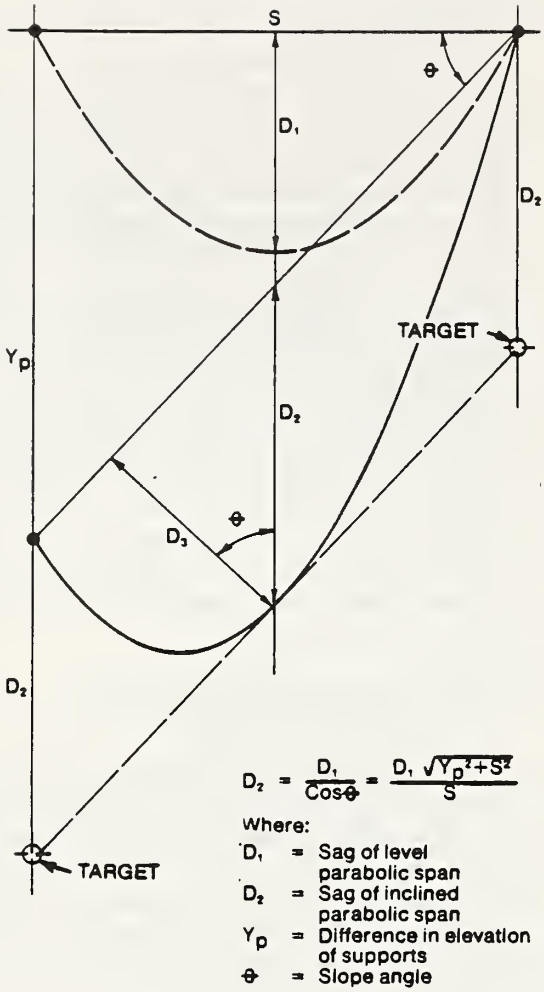


FIGURE VII-3

clined span very closely approximates the vertical sag of the equivalent level parabolic span. The apparent sag is defined by the NESC and is the maximum departure of the conductor in a given span from the straight line between the two points of support of the span. For the level parabolic span the apparent sag and vertical sag are identical and are the sag value found on the stringing sag tables. On Figure VII-3 this value of sag is designated as D_1. D_3 is the sag value of the apparent sag of the inclined parabola and is equal to D_1. D_2 is the value of the vertical sag of the inclined span and is equal to the distance below the supports which sighting targets must be set for line-of-sight sagging. D_2 is equal to D_1 divided by the cosine of the inclined slope of the span.

When sagging the conductor, the correct conductor sag can be determined by either of two methods.

- **Method 1**

Determine the slope span (S_S) between the two supports.

$$S_S = \frac{S_h}{\cos\theta}$$

or

$$S_S = \sqrt{S_h^2 - Y_p^2} \qquad \text{EQ VII-5A}$$

Where:

S_h = The horizontal distance between supports.

Y_p = The vertical difference in elevation between supports.

0 = Slope angle

$$\tan\theta = \frac{Y_p}{S_h}$$

From the stringing sag table determine the sag for a span equal to the slope span.

- **Method 2**

From the stringing sag table determine the sag for the horizontal span and then divide by the cosine of the slope angle.

$$D_2 = \frac{D_1}{\cos\theta} \qquad \text{EQ VII-5B}$$

Where:

D_2 = Vertical sag of inclined span

D_1 = Sag of level span, S_h

Generally correction of sags for inclined slopes will not be necessary if the slope angle is less than 10° or the percent slope is less than 15 percent, e.g. (Y_p) equals 15 meters in a 100 meter span, or 45 feet in a 300-foot span.

CHAPTER VII-6
CONDUCTOR INSTALLATION

A. GENERAL

The proper installation of conductor is one of the most important phases of distribution line construction. System reliability and the efficiency of line operation depend to a great extent on the proper conductor installation.

All conductor installations should be made according to REA Specifications for Construc-

tion, and in accordance with the conductor manufacturers' recommendations. Conductor engineering data and recommended methods for the proper installation of conductors are available from most conductor manufacturers.

The following guides for conductor installations are general in nature and are not intended to replace specific instructions provided by the manufacturer of the conductor.

B. UNLOADING AND STORAGE OF CONDUCTORS

Care should be exercised in unloading conductor reels from rail cars or trucks. They should not be dropped or allowed to roll freely down ramps. Cranes or other suitable equipment of adequate capacity should be used to avoid damage to the conductor or conductor reels. Careless handling during unloading, storage, transporting, and stringing may cause needless damage to the conductors while still on the reels.

If the conductor is to be stored for a period of time before use, it should be kept off the ground and otherwise protected from possible damage. Aluminum conductors in particular can become corroded quite rapidly when left in contact with moist earth.

C. CONDUCTOR STRINGING

Where possible, conductor should be payed out from rotating reels mounted on a vehicle which can be moved down the line as the conductor is payed out. This reduces probability of conductor damage due to dragging over fences, rocks, and other sharp objects.

Where this is not practical, the conductor can be pulled out if precautions are taken to prevent damage caused by dragging. Probability of such damage may be reduced by proper placing of rollers, rope cradles, or planking over such hazards.

After the conductor is payed out, it should be lifted to the support and placed in or on free-wheeling travelers (sheaves, blocks, or rollers) before pulling tension into the conductor. In order to equalize tensions in all spans during conductor sagging, it is necessary that the conductor be as free from friction as possible at the supports. The conductor should be pulled up far enough to clear all ground obstructions; however, it should be left semi-slack until ready to start the final stringing operation.

Tension stringing can also be used to pull out conductor with minimum probability of conductor damage. With this method the conductor should also be maintained under semi-slack tension until ready for final sagging.

When stringing conductor from a reel, it is necessary that proper tools be used to ensure the gripping of all strands. A woven wire basket type grip is usually used as this type of grip can be pulled through stringing sheaves or over arm sheaves when pulling out the conductor.

When pulling the conductor up to tension, come-alongs with long, straight, smooth parallel jaws should be used. Come-alongs or grips with notched jaws which might nick, bend, or otherwise damage the conductor should not be used. Bolted type come-alongs are usually used for pulling larger sizes of ACSR and all-aluminum conductors.

The length of section of line to be pulled up and sagged at one time is usually governed by the terrain, number of angles, road crossings and other obstructions, and, finally, by the length of conductor that can be uniformly sagged. Due consideration should be given to the impact of long spans and inclined spans in determining the spans which will be sagged in one operation.

In order to sag the conductor properly, the proper sagging tension must be applied in all spans in the section of the line being sagged. It is therefore necessary to determine if the supporting travelers are running free. An inspection should be made along the line section to determine if the conductors are coming up even. If not, this may be an indication that a sheave is not running free. Regardless of the method used at the poles to support the conductors during stringing and sagging operations, there will be some friction at every support. There will therefore be some tendency for the tension to be higher at the pulling end of the section being sagged and lower at the fixed end. It is sometimes necessary to ride the conductor at one or more points in the section being pulled in order to equalize the tension in all spans.

D. SELECTING THE SAG-CHECK SPANS

For relatively short stringing sections, it is usually acceptable to make one sag-check near

the center of the stringing section. As the length of the stringing section is increased, additional sag-check spans may be required. The number and location of check points required for a given stringing section may vary with factors such as conductor size, conductor tension, friction at the conductor supports, terrain, location of long spans, impact of inclined spans, etc.

The sag should be checked in spans with supports as nearly level as possible.

When first starting stringing operations, some experimenting should be done with the early sagging to determine the required frequency of sag-check spans. If it is found that the sag is within the lower tolerance on the fixed end, one sag-check span near the center will normally suffice. If the tolerances are exceeded, either shorten the stringing section length or add check-spans and manually work the conductor to bring the sag within allowable tolerances at both ends.

Where possible, the length of the sag-check span should be approximately equal to the theoretical ruling span of the section. It should not be less than the average span of the section and, at most, exceed the theoretical ruling span only slightly. Avoid sagging in spans shorter than the average span.

Sag errors are proportional to the square of the span length. For example, a 25 mm [2 in] error made in a 30 mm [100 ft] sag-check span, causes a 100 mm [8 in] error in a 60 m [200 ft] span, and a 225 mm [18 in] error in a 90 m [300 ft] span. On the other hand, a 25 mm [2 in] error made in a 90 m [300 ft] sag-check span results in a 6.25 mm [0.5 in] error in a 60 m [200 ft] span and only a 2.77 mm [0.22 in] error in a 30 m [100 ft] span.

If more than one sag-check span is being used in the stringing section, these should be as near the same length as possible or there might be some difficulty in coordinating the sagging tolerance.

E. WHEN TO SAG CONDUCTORS

Conductors, particularly aluminum conductors, stretch or creep rapidly when first brought to full or near full tension. It is therefore necessary to sag the conductor as rapidly as possible after it is brought to full sagging tension. Most initial stringing sag data are based on one hour of creep at the sagging tension. Delaying the sagging operation after the conductor has been brought to, or almost to, stringing tension, will cause the final sags to be different than predicted by the design criteria.

F. PREPARING TO CHECK SAG

The following items should be checked before starting the sagging operation.

- Be certain the stringing sag tables used for sagging are for the conductor design used in staking the line.
- Be sure to use the INITIAL stringing table (unless installing used conductor).
- Measure the sag-check span, don't rely on staking sheet dimensions.

G. CHECKING SAG

When checking sag, the temperature should be determined by means of a certified etched glass thermometer. The corresponding sag for this temperature should be obtained from the appropriate stringing sag table or chart. The temperature used should be as near as possible to that of the conductor being sagged. One way to do this is to tape the thermometer to a piece of scrap conductor and hang it where it will have the same exposure to the sun as the line conductor. Sagging thermometers are manufactured which are built into a case which simulates aluminum conductor. The thermometer should be placed about ten feet off the ground to avoid heat waves from the ground.

When sagging new conductor, use INITIAL stringing sag table. When sagging used conductor, use FINAL stringing sag tables. When used conductor is being added to an existing line, if the conductors are identical it is better to match the sag of the existing conductors. When new conductor is being added to an existing line, it is necessary to sag to the initial sag tables. Make certain the correct sag tables are being used for both the primary conductors and the neutral conductor. These may be sagged the same or differently depending on how the sags were coordinated in the design of the line.

If the span is inclined more than 10 degrees or 15 percent, correct the sag value as discussed in the preceding chapter. Details of the methods used for checking in the sag values are discussed in the next chapter.

H. SAGGING TOLERANCES

On short span distribution lines, it is frequently impossible to match the sag exactly to the calculated sag, so some permissible tolerance is required.

If the conductor design is based on one of the maximum permissible NESC conductor tension limits, it is recommended that the sag tolerance be 0 high and not more than 40 mm [1.5 in] low. If the conductor is sagged high, code tensions will be exceeded.

For conductor designs which are not controlled by one of the NESC conductor tension limits, it is recommended that sag tolerance not be more than 40 mm [1.5 in] high to 40 mm [1.5 in] low. These recommendations are based on sagging in spans of the length recommended hereinbefore. If it is necessary to check the sag in a span shorter than the average span, the tolerances should be reduced.

I. WHEN TO TIE-IN THE CONDUCTOR

After the conductors are pulled up to sag, they should be left one to four hours or more, depending on the length of the pull, to allow the conductor to "work." Immediately after pulling, the tension is generally greater at the pulling end than at the fixed end. This is due to drag or friction in the rollers or other conductor supports used during sagging. Any vibration of the conductors or supports resulting from wind or other causes will let the conductor work through the supports, thereby causing an equalizing of tensions between the spans.

The conductors should not be tied or clipped in until the conductors have had time to "work" or an unbalanced strain will be placed on the poles, arms, pins, insulators, tie wires, and conductors.

During this period of time another conductor phenomenon will occur which is called "creep." This is the permanent stretch of the conductor due to the applied tension and the conductor's own weight. If the sag of the conductor were to be rechecked at the end of the working period, it would be found that sag had increased. The amount of increase will vary with conductor type and design criteria. The conductor should not be resagged because of this; it is a natural occurrence.

A visual inspection of the conductor sag throughout the line section should be made before tying-in. The sags of the several conductors of the same type should be even. If not, the cause could be either incorrect sagging or failure of one of the conductors to "work" because of a locked roller or similar cause. Remedial action should be taken before clipping-in.

At this stage, if one of the conductors is sagged wrong, it should be resagged to match the other conductors, not the original initial stringing sag.

J. REPORTING CONDUCTOR SAG CHECKS

A record should be kept for each conductor sag check.

The foreman in charge of the sagging operation is responsible for the preparation of this record, which is signed and turned over to the inspector or engineer.

The inspector should also prepare a record of the sag checking. Table VII-1, Tabulation of Wire Sag Check, shows a typical sample form for the stopwatch method of sag checking.

If the sagging crew and the inspector are both checking sag at the same time, only one report is required but both the stringing foreman and inspector should sign the report form.

CHAPTER VII-7
METHOD FOR CHECKING CONDUCTOR SAG

A. GENERAL

The following guide provides useful information for checking the sag of overhead conductors.

The sag check methods discussed include the following:

- Stopwatch method.
- Direct target method.
- Dynamometer method.

Generally the method selected for a specific case will depend on the preference of the user, the suitability of the method to the particular span in which the sag is being checked, and equipment available for checking.

TABLE VII-1

TABULATION OF WIRE SAG CHECK
(EXAMPLE)

Work Order No.____________

Date____________

Type & Size Conductor________ Ruling Span________ Date Sagged________

________ Span Between Poles*________ And________

Temperature________ Correct Sag________Correct Time Sec.________

Road Phase • Time________ Sec. Sag________

Center Phase • Time________ Sec. Sag________

Field Phase • Time________ Sec. Sag________

Neutral • Time________ Sec. Sag________

Remarks________

*Insert Sheet and Pole No.

Checked By________

This tabulation to be made in duplicate with one copy to the stringing foreman at end of each day's checking. Original copy to be retained in inspector's files.

The checker should endeavor to check sags at the same time the conductor is installed and sagged, particularly with ACSR or aluminum conductors. These conductors creep rapidly when first installed and dissimilar results will be obtained within a time interval of only a few hours.

For the methods described hereinafter, D is the sag given in the Stringing Sag Tables and is measured vertically at midspan (not a low point of sag). The low point of sag is exactly at midspan only when the supports are exactly level.

The point of conductor support is the actual elevation of conductor at point of attachment. When necessary to check sag in spans with angle structures, the angle of swing of the insulator string must be taken into consideration if the location of conductor support is calculated rather than measured.

B. STOPWATCH METHOD

In this method a traveling wave is generated in the span by striking the conductor at one support and the time required for the wave to make a certain number of reflected returns is measured. The method is most applicable to light conductors supported on pin insulators; however, satisfactory results can be obtained for conductors supported on suspension insulators. This method proves unsatisfactory on dead end spans or spans with splices because the reflected wave is garbled when it strikes the insulator string or splice. Also, as span length or conductor size increases, this method becomes less accurate. A strong wind will also tend to modify the wave and make it difficult to determine the exact time of its return. The method is not recommended for use on inclined spans with a slope angle in excess of 10°.

The wire should be given an impulse close to one support (approximately one meter or three feet) either by striking a blow or by jerking with a rope or heavy cord and the stopwatch started simultaneously. The impulse will cause a wave to travel to the far support. At the far support

this wave will be reflected back to the near support where it will again be reflected and so on until it dies out. At the third return of the wave to the near support, the watch should be stopped and the time read. The sag in meters or inches for the time read can then be obtained from Table VII-2 included hereafter.

Actually, it does not make any difference whether the first three returns of the wave or any other three consecutive returns are timed. The time for three complete cycles is the same throughout the period the conductor is in wave. A checker may therefore use any three consecutive returns.

Many checkers prefer to start the sequence on the first return of the wave rather than on the impulse. The count procedure then is as follows: count "hit" (impulse given), "start" (first return), "one" (second return), "two" (third return), and "three" (fourth return). Start the watch on "start" and stop it on count "three."

The time-sag table gives timing for the third, fifth and tenth returns. The longer periods usually will give better accuracy and may be used in cases where the wave will continue long enough to count the greater number of cycles.

To eliminate errors which occasionally occur, the checking procedure should be repeated at least three times to obtain the final result. If, in comparing the result obtained with that of the stringing sag tables used on the project, there appears to be an unwarranted difference, a further check should be made by actually measuring the span to make certain the span length used for sagging is correct.

It is recommended the time for the third, fifth, or tenth return of the wave be used in sag measurement and the values of sag taken directly from the table on the following page. Where this is not possible, the following formula may be used to compute the sag for any number of return waves:

$$D = \frac{K T^2}{2N} \qquad \text{EQ VII-7A}$$

Where:

D = Sag in meters, feet or inches

K = 1.227 meters per second² (use when sag is in meters)

K = 4.025 feet per second² (use when sag is in feet)

K = 48.3 inches per second² (use when sag is in inches)

T = Time in seconds

N = Number of return waves counted

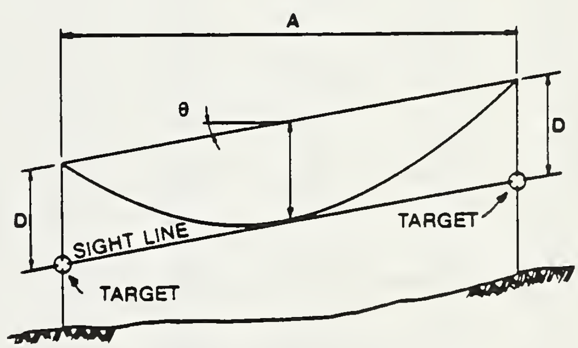
C. DIRECT TARGET METHOD

Using this method, a target is set at a distance equal to the desired sag below the conductor support on one structure. A sight is then taken from the adjacent structure at an equal distance below its support and the conductor is sagged to this line of sight. (See Figure VII-4) This method is limited to spans in which the sag is less than the distance from ground line to conductor support.

This method is probably the most accurate method of sagging conductor when proper care is used in placing targets and the sighting is done with an instrument with horizontal cross hairs.

Dimension "D" must be the measured distance below the conductor support used during the sagging, i.e., the roller of the stringing traveler. Do not use the distance below the insulator groove for sag checking. Dimension D is the sag value for span A as determined from the stringing sag table, except that if the slope angle θ is greater than 10 degrees, D should be corrected by dividing by the cosine of angle θ.

If the temperature changes slightly after the target and sighting point have been located, rather than relocate both points, it is permissible to move either the target or sighting point up or down a distance twice the value of the decrease or increase in sag caused by the temperature change.



DIRECT TARGET METHOD

FIGURE VII-4

TABLE VII-2
TIME SAG TABLE

Meters	Inches	Return of Wave 3rd Time (Sec.)	Return of Wave 5th Time (Sec.)	Return of Wave 10th Time (Sec.)	Meters	Inches	Return of Wave 3rd Time (Sec.)	Return of Wave 5th Time (Sec.)	Return of Wave 10th Time (Sec.)
0.1	4	1.7	2.9	5.7	1.5	59	6.6	11.1	22.1
0.125	5	1.9	3.2	6.4	1.525	60	6.7	11.1	22.3
0.15	6	2.1	3.5	7.0	1.55	61	6.7	11.2	22.5
0.175	7	2.3	3.8	7.6	1.575	62	6.8	11.3	22.7
0.2	8	2.4	4.0	8.1	1.6	63	6.9	11.4	22.8
0.225	9	2.6	4.3	8.6	1.625	64	6.9	11.5	23.0
0.25	10	2.7	4.5	9.0	1.65	65	7.0	11.6	23.2
0.275	11	2.8	4.7	9.5	1.675	66	7.0	11.7	23.4
0.3	12	3.0	4.9	9.9	1.7	67	7.1	11.8	23.5
0.325	13	3.1	5.1	10.3	1.725	68	7.1	11.9	23.7
0.35	14	3.2	5.3	10.7	1.75	69	7.2	11.9	23.9
0.375	15	3.3	5.5	11.1	1.775	70	7.2	12.0	24.1
0.4	16	3.4	5.7	11.4	1.8	71	7.3	12.1	24.2
0.425	17	3.5	5.9	11.8	1.825	72	7.3	12.2	24.2
0.45	18	3.6	6.1	12.1	1.85	73	7.4	12.3	24.6
0.475	19	3.7	6.2	12.4	1.875	74	7.4	12.4	24.7
0.5	20	3.8	6.4	12.8	1.9	75	7.5	12.4	24.9
0.525	21	3.9	6.5	13.1	1.925	76	7.5	12.5	25.1
0.55	22	4.0	6.7	13.4	1.95	77	7.6	12.6	25.2
0.575	23	4.1	6.8	13.7	1.975	78	7.6	12.7	25.4
0.6	24	4.2	7.0	14.0	2.0	79	7.7	12.8	25.5
0.625	25	4.3	7.1	14.3	2.025	80	7.7	12.8	25.7
0.65	26	4.4	7.3	14.6	2.05	81	7.8	12.9	25.9
0.675	27	4.5	7.4	14.8	2.075	82	7.8	13.0	26.0
0.7	28	4.5	7.6	15.1	2.1	83	7.9	13.1	26.2
0.725	29	4.6	7.7	15.4	2.125	84	7.9	13.2	26.3
0.75	30	4.7	7.8	15.6	2.15	85	7.9	13.2	26.5
0.775	31	4.8	7.9	15.9	2.175	86	8.0	13.3	26.6
0.8	31	4.8	8.1	16.2	2.2	87	8.0	13.4	26.8
0.825	32	4.9	8.2	16.4	2.225	88	8.1	13.5	26.9
0.85	33	5.0	8.3	16.6	2.25	89	8.1	13.5	27.1
0.875	34	5.1	8.4	16.9	2.275	90	8.2	13.6	27.2
0.9	35	5.1	8.6	17.1	2.3	91	8.2	13.7	27.4
0.925	36	5.2	8.7	17.4	2.325	92	8.3	13.8	27.5
0.95	37	5.3	8.8	17.6	2.35	93	8.3	13.8	27.7
0.975	38	5.3	8.9	17.8	2.375	94	8.3	13.9	27.8
1.0	39	5.4	9.0	18.1	2.4	94	8.4	14.0	28.0
1.025	40	5.5	9.1	18.3	2.425	95	8.4	14.1	28.1
1.05	41	5.6	9.3	18.5	2.45	96	8.5	14.1	28.3
1.075	42	5.6	9.4	18.7	2.475	97	8.5	14.2	28.4
1.1	43	5.7	9.5	18.9	2.5	98	8.6	14.3	28.6
1.125	44	5.7	9.6	19.2	2.525	99	8.6	14.3	28.7
1.15	45	5.8	9.7	19.4	2.55	100	8.7	14.4	28.8
1.175	46	5.9	9.8	19.6	2.575	101	8.7	14.5	29.0
1.2	47	5.9	9.9	19.8	2.6	102	8.7	14.6	29.1
1.225	48	6.0	10.0	20.0	2.625	103	8.8	14.6	29.3
1.25	49	6.1	10.1	20.2	2.65	104	8.8	14.7	29.4
1.275	50	6.1	10.2	20.4	2.675	105	8.9	14.8	29.5
1.3	51	6.2	10.3	20.6	2.7	106	8.9	14.8	29.7
1.325	52	6.2	10.4	20.8	2.725	107	8.9	14.9	29.8
1.35	53	6.3	10.5	21.0	2.75	108	9.0	15.0	29.9
1.375	54	6.4	10.6	21.2	2.775	109	9.0	15.0	30.1
1.4	55	6.4	10.7	21.4	2.8	110	9.1	15.1	30.2
1.425	56	6.5	10.8	21.6	2.825	111	9.1	15.2	30.3
1.45	56	6.5	10.9	21.7	2.85	112	9.1	15.2	30.5
1.475	58	6.6	11.0	21.9	2.875	113	9.2	15.3	30.6

On long spans, it becomes difficult to sight the conductor with the naked eye and some type of optical aid may be necessary. An instrument with horizontal cross hairs for sighting the low point of conductor sag against the target is preferred. Sagging scopes with devices for clamping on poles or towers are available. Bracket-mounted transits may also be used but may be unsatisfactory on flexible structures because of sway and vibration.

D. DYNAMOMETER METHOD

Dynamometers or tension meters may be used for sagging conductors. This is one of the most accurate methods when high quality equipment is used by trained experts. The method is not generally recommended for distribution systems for the following reasons: the lower cost instruments are not highly accurate and get out of adjustment. Calibration equipment is required for checking and making adjustments. The calculated tension of the span is the average tension whereas the tension measured by the dynamometer is the tension at one specific point in the span, and this tension can be either higher or lower than the calculated average tension. The dynamometer should be located in an overhead span in which the conductor supports are approximately level and not more than 10° out of level. The value of tension normally used is that shown on the stringing sag table for the conductor temperature at the time of sagging. The tension shown on the table is the calculated average tension for the design ruling span. For very long spans, it may be necessary to calculate the resultant tension using equations given in Part IV.

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National Electrical Safety Code Interpretations, 1978-1980 (1981).

REA Publications[2]

REA Bulletin 40-6, **Construction Methods and Purchase of Materials and Equipment.**

REA Bulletin 40-7, **National Electrical Safety Code**

REA Bulletin 43-5, **List of Materials Acceptable for Use on Systems of REA Electrification Borrowers.**

REA Bulletin 62-1, **Design Manual for High Voltage Transmission Lines.**

REA Bulletin 80-5, **Conductor Installation for Electric Distribution Lines.**

REA Bulletin 160-1, **Engineering and Operations Manual for Rural Electric Systems.**

REA Form 801, **Specifications and Drawings for 34.5/19.9 kV Line Construction.**

REA Form 803, **Specifications and Drawings for 24.9/14.4 kV Line Construction.**

REA Form 804, **Specifications and Drawings for 12.5/7.2 kV Line Construction.**

REA Spec No. DT-5C, **Specification for Wood Poles, Stubs, and Anchor Logs and Preservative Treatment of these Materials.**

REA Staff Report, **Dimensions and Resisting Moments of Wood Poles.**

Miscellaneous Publications[3,4]

Specifications and Dimensions for Wood Poles, American National Standards Institute, ANSI 05.1-1979.

Metric Practice Guide, American National Standards Institute, ANSI Z210.1

Metric Manual, U.S. Department of Interior, Bureau of Reclamation.

NOTES: The above publications are available from the following sources:

1. Current NESC publications are available from IEEE Service Center, 445 Hoes Lane, Piscataway, NJ 08845. For information concerning availability of superceded publications, contact IEEE Standards Office, 345 East 47th St., New York, NY 10017.
2. REA publications are available from various sources, for information, contact U.S. Department of Agriculture, Rural Electrification Administration, Washington D.C., 20250.
3. ANSI publications are available from American National Standards Institute, 1430 Broadway, New York, NY 10018.
4. U.S.D.I. publications are available from the Superintendent of Documents, U.S. Government Printing Office, Washington, D.C. 20402.

APPENDIX A
METRIC CONVERSION

A. INTRODUCTION

The transition from the use of the U.S. Customary Systems of Units to the SI Metric System of Units (International System of Units) is underway in the electric utility industry of the United States. During the useful life of this edition of this design manual, there will be an increasing need to know how to properly perform conversions between the U.S. Customary (customary) and the SI Metric (metric) systems of units.

This appendix has been prepared specifically to assist the users of this design manual. Conversion factors included are those that will be commonly encountered in the design of overhead distribution lines. The appendix is limited to basics and not intended to be a complete metrication manual. The American National Standards Institute, Metric Practice Guide (ANSI Z210.1) and the "Metric Manual" prepared by the U.S. Department of the Interior, Bureau of Reclamation, are recommended for those interested in additional study.

The appendix first discusses the procedures, precisions, and accuracies required for rounding numbers and then applies these procedures in the methods for converting numbers. The methods for making soft conversions of measured values are discussed as well as methods for making both soft and hard conversions of defined limiting values.

Table A-1 provides conversion factors for the dimensions commonly used in overhead line design.

B. EXACT AND ROUNDED QUANTITIES

Numerical quantities used in engineering computations are expressions of dimensional quantities or are derived from such quantities. The numbers which represent these quantities may be exact numbers or rounded numbers. These two categories of numbers are treated differently in calculations.

1. Exact Numbers

Most exact numbers encountered in line design computations are those found in codes, standards, and design guides, which have been defined as safety factors, basic dimensions, tolerances, and limiting dimensions. Such defined numbers are based on some exact quantity of a defined basic unit of measurement.

Exact numbers are exactly precise and exactly accurate. All digits of exact numbers are significant including all zeros to the required decimal position. Two exact numbers can be added, subtracted, or multiplied and the result will be exact. When an exact number is divided by an exact number, the ratio is exact but not necessarily the quotient, i.e., the ratio 5/9 is exact but the quotient cannot be expressed as an exact number. If the number of digits of an exact number is too great to be handled conveniently in a computation and the number is rounded, the number must then be treated as a rounded number.

Defined numbers based on a system of units cannot be converted as an exact number in another system of units unless the conversion factor is also an exact number.

2. Rounded Numbers

All numbers which are not exact, are rounded numbers. Hence most numbers used in engineering calculations are rounded numbers and therefore imprecise.

The majority of these rounded numbers represent measured values. Measured values are determined by comparison with a defined unit of measurement. Measured values can be no more precise than the method of measurement, and all measuring devices have some degree of imprecision.

A rounded number has a degree of precision. It is desirable that the rounded result of a calculation maintain the same degree of precision as the numbers put into the calculation. It is therefore necessary to conform to certain rules of precision when making calculations. If the rules are not maintained, the accuracy of the result will deteriorate with each added step in the calculation.

C. ROUNDING NUMBERS

1. General

The art of rounding numbers is basically skill in determining the proper number of significant digits to be retained to provide a realistic tolerance for the rounded number.

2. Significant Digits of a Number

Numbers which represent quantities or values of dimensions are expressed by a series of digits

consisting of the integers 0 to 9. Those digits of the number which are necessary to define the value to a desired precision or accuracy are said to be the significant digits of the number. The digits which are not significant are dropped or rounded off. If the dropped digits are to the left of the decimal point of the number, the insignificant digits are replaced with insignificant zeros.

3. Rounding a Number

A rounded number represents a value that is not exact but contains enough significant digits to adequately define the measured dimension or quantity. The last significant digit must then represent the closest approximate value of itself together with the digits to be dropped. Therefore the integer value of the rounded last digit may change from the integer value prior to rounding. For example, the number 2678, when rounded to three significant digits, becomes 2680 and the last digit has changed from 7 to 8.

The rounding of whole numbers may be expressed in many different ways such as "round to the nearest one hundred" or "round to the nearest 25." A whole number can be rounded to the nearest integer or any multiple of 2, 5, or 10.

In conversion calculations, rounding generally means the rounding of the last significant digit to any integer from 0 to 9. Any other roundings are essentially restricted to rationalized conversions which are discussed later.

4. Rounding Interval

The rounding interval is the numerical separation between permissible roundings. For conversion calculations, the rounding is generally to the closest integer; therefore, the rounding interval is 1. If the rounding were to the closest multiple of 5, the rounding interval would be 5.

5. Tolerance of a Rounded Number

The tolerance of a rounded number is plus or minus one half of the rounding interval. For a rounding interval of 1, the tolerance is ± 0.5. For a rounding interval of 5, the tolerance is ± 2.5.

6. Decimal Position of the Rounded Number

The decimal position of the rounded number is defined as the position of the last significant digit of the number with respect to the decimal point of the number. The decimal position is then described as being so many (digit) positions to the right or left of the decimal point.

The decimal position of a whole number is what gives a value to the tolerance of the number. If the tolerance of the last significant digit is ± 0.5 and the digit is in the second position to the left of the decimal point, the tolerance of the whole number becomes ± 5.

To change the magnitude of the tolerance, it is necessary to change the number of significant digits.

The tolerance of the number should approximate the known or estimated tolerances actually used in measuring the numerical value. Thus the tolerance value determines the decimal position of the last significant digit which in turn determines the number of significant digits of the whole number.

7. Accuracy of a Rounded Number

The measure of accuracy of a rounded number is defined as the quotient of the tolerance of the whole number divided by the whole number. The degree of accuracy is usually expressed as a percentage. The accuracy is an expression of the error-free level of the number as a function of its own magnitude; therefore, the smaller the percentage, the greater the accuracy.

Thus, if the number 2530 is known to have been rounded to three significant figures, using a rounding interval of ten, the tolerance is ±5, and the accuracy is found to be 0.198 percent.

$$\text{Accuracy (percent error)} = \frac{5 \times 100\%}{2530} = 0.198$$

Sufficient digits must be retained to express the necessary accuracy but the number retained should not imply greater precision (tolerance) than warranted by the use to be made of the rounded number.

The above again demonstrates the importance of the relationship between the tolerance and significant digits of the rounded number.

The range of accuracy of numbers as a function of the number of significant digits when the number is rounded to the closest integer is indicated below.

Number of Digits	Range of Accuracy (Percent Error)
1	50 - 5%
2	5 - 0.5%
3	0.5 - 0.05%
4	0.05 - 0.005%

8. Selection of Realistic Tolerance

From the preceding discussion, it is clear that

the rounding procedure is very much dependent on the selection of tolerance. Both the precision of the number based on decimal position and the accuracy of the number are functions of the tolerance.

The tolerance of the number should be a realistic approximation of the tolerance actually used in measuring the value and at the same time provide a reasonable accuracy. These two requirements will not always be compatible and some judgment may have to be exercised. The following guidelines will generally provide adequate results.

- Where the tolerance used for measured values is known or can be estimated, such tolerances should be used as the basis for rounding numbers.
- Desired accuracy of the number can be used to determine the tolerance of a number when the tolerance used for measurement cannot be determined. Such numbers most often occur as results of multiplications and divisions involving measured values. The degree of accuracy should be as required to maintain the accuracy of the computation.

D. ACCURACY AND PRECISION OF CALCULATIONS

1. General

Accuracy and precision are both terms which express measures of quality. In calculations which involve rounded numbers, these terms are used for two distinct measures of quality.

2. Precision of a Computation

The precision of a computation is determined by the precision of the rounded numbers involved in the computation.

The precision of the numerical result of the computation shall not be greater than the precision of the least precise rounded number included in the computation. Conversely, if a specified precision or minimum accuracy is required of the result, then the precision of all rounded numbers used in the computation must be sufficiently precise to yield a result with the required accuracy or precision. Thus it can be said that the precision of a computation expresses the degree of mutual agreement between the rounded numbers of the computation.

The determination of the least precise rounded number is accomplished by comparing the numbers in terms of the three following rules of precision.

- **Significant Digits**
  The number with the fewest significant digits is the least precise number. Thus, the number 2340 is less precise than the number 2341, unless it is known that the zero of the first number is significant, in which case the numbers would be equally precise.
- **Decimal Positions**
  For numbers representing similar quantities, the number which has the last significant digit the furthest to the left with respect to the decimal position is the least precise number. Thus, the number 2341 is less precise than the number 234.1.
- **Tolerance**
  For numbers which are otherwise equally precise, the number with the largest tolerance is the least precise number.

3. Precision of Addition and Subtraction

For addition and subtraction, the primary rule of precision is the decimal position rule. The result shall contain no significant digits further to the right than occurs in the least precise number used in the computation.

Consider the addition calculation in (a) below:

(a)	1.2676	(b)	1.268
	13.21		13.21
	5.361		5.361
	1.36012		1.360
	21.19872		21.199
		(c)	21.20 Rounded

The total of (a) indicates a precision which is not valid. Rounded to one less digit, it still is not valid.

The second rule for addition and subtraction is that all numbers should first be rounded to one significant digit further to the right than the least precise number as shown in (b). The result should be rounded to the position indicated by the least precise number as shown by (c).

4. Precision of Multiplication and Division

For multiplication and division, the primary rule of precision is the significant digit rule. The product or quotient shall contain no more significant digits than are contained in the least precise number used in the calculation.

Thus in the calculation $6.871\ 4 \times 2.6 = 17.865\ 64$, the product is rounded to 17.9.

5. Accuracy of a Calculation

The accuracy of a computation which includes rounded numbers is determined from the numerical result of the calculation. It is equal to the quotient of the tolerance divided by the significant digits expressed as a percentage.

E. GENERAL RULES FOR CONVERSIONS

1. General

The following rules for conversion are the common rules used for converting measured values from the customary system of units to the metric system of units and vice versa.

Calculations should be made using the system of units desired for the results of the computation. Therefore, conversion of the data should be performed prior to making the computations. Thus, if the results are to be presented in metric units any data based on customary units must be converted prior to computation. Likewise, if the results are to be in customary units, any metric unit data must be converted prior to computation.

Table A-1 provides conversion multiplication factors for converting from the customary system to the metric system. For conversions from the metric system to the customary system, divide the metric unit by the conversion factor.

In Table A-1, conversion factors which are imprecise or not exact are rounded to seven significant digits. Conversion factors which are exact have only the required number of digits and are followed by an asterisk(*).

The proper conversion procedure is to multiply or divide the measured value by the conversion factor exactly as given in Table A-1, then round the result to the desired degree of precision and accuracy using the guidelines given in the preceding section of this appendix.

For conversions of measured values, the converted value is rounded to the nearest rounding interval, usually the nearest integer. The rounding of limits follows different procedures which are discussed in the following sections.

2. Soft Conversions

Conversions calculated exactly in conformance with the preceding general rules and to the precision and accuracy required by these rules are commonly referred to as "soft" conversions. Soft conversions are exact conversions or as nearly exact as permitted by the precision rules of conversion. Customary-to-metric soft conversions are normally presented in the following manner: 48.89°C (120°F).

In this design manual, the metric value is always given first followed by the customary value enclosed with these parentheses ( ).

The manual also includes "hard" conversions which are presented as follows: 50°C [120°F]. Note that the customary · value is enclosed within brackets [ ] to distinguish the hard conversion from a soft conversion. The procedure for hard conversions is discussed later in this appendix.

F. CONVERSIONS INVOLVING LIMITS

1. General

A limit is a defined value which a varying quantity may approach but may not exceed. Any defined value in a code, standard, or design guide which is not to be exceeded is therefore a limit. Defined tolerances are also limits.

Almost every defined value found in the NESC is therefore a mandatory limit and almost every defined value in a design guide is a voluntary limit. Therefore, most distribution line computations which involve conversions will also involve limits.

Conversion computations can be separated into two major categories, these being those which involve the conversion of the limit, and those which involve measured values which may be compared to a limit.

2. Conversion of Measured Values

Most, but not all, converted measured values, or computed values derived from converted values, will eventually be compared to a limit. These conversions should conform to the precision and accuracy guidelines for a soft conversion as discussed in the preceding sections. The last significant digit is rounded to the closest whole integer.

3. Conversion of Limits

Conversions of limits are of two types which are distinguished by the use to be made of the converted values. These are:

- Converted limit values which represent the limit values as defined in the original system of units. Such conversions are "soft" limit conversions.
- Converted limit values which are used as a basis for redefining the limit value to a

numerical value which is practical for the new system of units. Such conversions are "rationalized" or "hard" conversions, and will be discussed in a later section of the appendix.

Limits are exact numbers defined in a specific system of units. Limits defined in either the U.S. Customary System or the SI Metric System of Units usually cannot be converted exactly to the other system, or at least cannot be converted exactly to a practical numerical value in the other system. It is therefore necessary to convert the exact value to an approximate rounded value. The conversions should follow the guidelines for "soft" metric conversions as discussed in the preceding sections, with one exception.

If the converted limit cannot be exact, it must be more restrictive than the original limit. To assure this requirement is satisfied, the rounding of the last significant digit must be to the more restrictive integer rather than to the closest integer.

If the limit is a "not less than" limit, the rounding is to the larger integer. If the limit is a "not more than" limit, the rounding is to the smaller integer.

The precision of the converted limit should be to the same degree as the values to be compared to it.

G. RATIONAL OR HARD CONVERSIONS

1. General

Rationalized or hard conversions are conversions of limit values which are rounded to convenient practical numerical values to use as new exact limit values in the second system of units.

As the transition period progresses in the United States, the new standards will make use of rationalized conversions. Thus, most defined limits will actually change in magnitude when the converted standard is adopted.

2. Practical Rationalized Limit Values

Practical values for hard conversions should be numerical values which will be easy to remember. Such numbers will be those similar to those found in the NESC, which are based on the customary system of units. The accuracy error should generally not exceed two-and-one-half percent.

The following guide has been used for hard conversions demonstrated or used in this design manual. This guide is that which has been proposed for conversion of the NESC limits.

- **Dimension Values Other than Temperature**
  For numbers where the first two digits are from 20 to 99, round to two digits rounded to nearest integer.

  For numbers where the first two digits are from 10 to 19, round to three digits rounded to nearest zero or 5.
- **Temperature Values**
  Round to nearest 5°C. This is a small error when based on the SI Metric standard Kelvin temperature.
- **Decimal Position Precision**
  The decimal position precision is maintained throughout the range of converted values of one kind. If the range of values is of such magnitude that above rounding rules would otherwise change the decimal position precision, the precision is based on the midrange of values.

3. Application of Rationalized Values

Rationalized or hard metric conversions of limit values can be used prior to the metric conversion of the applicable standard, provided the following conditions are satisfied.

- The resulting metric hard conversion is more restrictive than the soft conversion of the limit value.
- If the resulting metric hard conversion is less restrictive than the soft conversion of the limit value, the hard conversion may be used if the design guide includes a design tolerance which is greater than the difference between the hard conversion and the soft conversion of the limit value.
- If the converted value is a voluntary design limit and more limiting or not limited by any applicable standard or safety code.

4. Hard Conversions Used in Design Manual

Hard conversions have been used in this design manual to provide practical rationalized values for the following conversion categories:

- NESC limit values where a proposed value has been established by the IEEE-T&D Metrication Working Group for use in a future metricated version of the NESC.
- Converted limit values which were originally arbitrarily established by REA.
- Generally accepted industry guide values which are not limited by a specific standard or code.

H. FORCE, WEIGHT, AND MASS

In the SI metric system of units, there is one basic unit for force and one basic unit for mass; these units are the newton (N) and the kilogram (kg), respectively. In the U.S. customary and traditional cgs-MKS metric systems, the units to be used for force and mass are many and are confusing, at best. And there is always the question concerning weight; is this a mass or is it a force, and will the same definition be applicable everywhere, including other parts of the solar system?

In the U.S. customary system, the pound has played a dual role; it is the unit most people use to describe both mass and force. This dual relationship was perpetuated in the traditional metric systems with the use of kilogram and kilogram (force); this dual identity is not permitted in SI. The customary term of weight is not used in SI; it also carries a double definition.

To clarify the difference between SI and customary units, the following definitions and discussions are presented so that these units of measure can be fully understood and an accurate comparison with the SI units can be made.

- **Weight** — Weight has been the method of describing an object's mass by measuring how much gravitational force the object exerts. This relationship has been widely accepted even though it is not constant because gravitational forces vary throughout the world and are significantly different in outer space. On Earth, a 200-pound man "weighs" 200 pounds, but on the Moon, he "weighs" only 33 pounds.

  Although weight is more commonly used to describe mass, it is actually a measure of force, the force resulting from gravity.

- **Pound (weight) and Pound (force)** — The pound is the traditional unit of measure for the weight of an item. Since an object's weight will change with the gravitational field and since mass is constant, it follows that pound is a unit of force. The term "pounds (force)" is commonly used and widely accepted; however, identification as a force is redundant and not necessary.

- **Pound (mass)** — The use of this term is a means of expressing mass as a function of the Earth's gravity; it is a quantity (mass) which will exert the force of 1 pound at standard gravitational attraction. The use of "pound" alone is technically a force; in common use, it is generally and incorrectly used as a mass term.

- **Slug** — The slug is technically the U.S. customary unit of measure for mass. This terminology has very limited recognition, which contributes to the difficulty in differentiating between weight (force) and mass.

  A slug subjected to a force of 1 pound will move with an acceleration of 1 ft/sec^2, and a slug subjected to gravitational acceleration exerts a force of 32.174 pounds. Note that Newton's law states: force equals mass times acceleration; $F=(m)(a)$.

- **Kilogram (force)** — This terminology is a means of expressing the force exerted by a mass of 1 kg at mean sea level; this equals 9.806 65 newtons. This terminology is not SI and its use is an erroneous attempt to perpetuate the confusion of the U.S. customary system regarding weight, force, and mass. Do not use this terminology.

- **Kilogram** — The kilogram is a measure of an object's mass; the mass of an item is constant and does not change with the gravitational field or its rate of acceleration. The use of the term "kilogram (mass)" is redundant and should be avoided.

- **Newton** — The newton is the SI unit of force. Using Newton's equation of $F=m \times a$, a newton is 1 kilogram times 1 meter per second squared. Acting under Earth's gravitational pull, a mass of 1 kg exerts a force of 9.806 65 newtons.

A general summary of SI rules covering mass and force is listed below:

1. The SI unit for mass is the kilogram.
2. The SI unit for force is the newton. Do not use kilogram (force).
3. Gravity is not an essential element of the SI system.
4. The use of weigh and weight should be avoided; they should not be used to indicate the measuring process or the measure of mass. Recommendation: Rather than say "it weighs" say "it has a mass of." Rather than "weighing the object," say "measuring the object's mass." Similar sentence structure changes can be made for other tenses, subjects, etc.

This design manual deals with both the SI metric and the customary systems of units. In discussions applicable to both systems the terms "weight" and "force (weight)" are used and are synonymous. Weight and pounds shall be interpreted to mean "force" and "pounds force" unless otherwise indicated.

As seen from the above, in the SI metric system, kilograms (mass) cannot be changed to newtons (force) by a dimensionless conversion factor. The change must be accomplished by multiplying by gravitational acceleration. Gravitational acceleration on the surface of the earth varies with altitude and latitude. However, for the purpose of line design, a value of 9.8 m/sec^2 will provide sufficient accuracy.

TABLE A-1

SI CONVERSION FACTORS[1]

To Convert From	To	Multiply by
Length		
foot (ft)	meter (m)	0.304 8*
inch (in)	meter (m)	0.025 4*
inch (in)	millimeter (mm)	25.4*
mile (mi)	kilometer (km)	1.609 334*
Area		
square foot (ft^2)	meter² (m^2)	0.092 903 04*
square inch (in^2)	meter² (m^2)	0.000 645 16*
square inch (in^2)	millimeter² (mm^2)	645.16*
kilo circular mil (kcmil)	millimeter² (mm^2)	0.000 506 707 5
Volume		
cubic foot (ft^3)	meter³ (m^3)	0.028 316 685
cubic inch (in^3)	meter³ (m^3)	0.000 016 387 06
cubic inch (in^3)	millimeter³ (mm^3)	0.016 387 06
Mass		
pound mass (avoirdupois) lb	kilogram	0.453 592 4
Force		
pound force (lbf)	newton (N)	4.448 222
Bending Moment		
pound foot (lb • ft)	newton meter (N • m)	1.355 818
pound inch (lb • in)	newton meter (N • m)	0.112 984 8
Bending Moment Per Length		
pound foot/foot (lb • ft/ft)	newton meter/meter (N • m/m)	1.355 818
Pressure & Stress		
pound force/foot², psf (lb/ft^2)	pascal (Pa)	47.880 26
pound force/inch², psi (lb/in^2)	pascal (Pa)	6 894.757
Force Per Length		
pound/foot (1lb/ft)	newton/meter (N/m)	14.593 90
Velocity		
mile per hour (mi/h)	meter per second (m/s)	0.447 040 0
mile per hour (mi/h)	kilometer per hour (km/h)	1.609 344*
foot per second (ft/s)	meter per second (m/s)	0.304 8*
Temperature		
degree Fahrenheit (t_f°F)	degree Celsius (t_c°C)	$t_c = (t_f - 32) \div 1.8$*
Temperature Internal		
degree Fahrenheit (°F)	degree Celsius (°C)	9/5*

*Conversion factor is exact.

[1]The conversion factors included herein are from the International Organization for Standardization publication ISO/R31/Part III-1960 as reprinted in the American Society for Testing and Materials (ASTM) Metric Practice Guide E 380-72.

APPENDIX B
CONDUCTOR AND GUY WIRE STRENGTH AND LOADING DATA

The following Tables B-1 and B-2 provide strength and mechanical data for those ACSR and 6201 aluminum alloy conductors included in REA Bulletin 43-5, List of Materials which are commonly used for distribution line construction.

The tables provide vertical, transverse, and total resultant (including NESC k factor) vector loads on the conductors under NESC conditions for the general loading districts, extreme wind loading, and six-pound-per-square-foot wind loading for conductor blow-out. The values given are based on the 1981 NESC.

Table B-3 provides breaking strength and allowable load data for guy wire included in the List of Materials which are commonly used in distribution line guying. The allowable load is the breaking strength multiplied by the NESC 0.9 safety factor.

TABLE B-1

NESC DISTRICT LOADINGS

			Light .00'Ice 9 Lb Wind K=.05			Medium .25'Ice 4 Lb Wind K=.20			Heavy .50'Ice 4 Lb Wind K=.30					
Name	Size	Strand	Vert. Lb/Ft	Trans. Lb/Ft	Total Lb/Ft	Vert. Lb/Ft	Trans. Lb/Ft	Total Lb/Ft	Vert. Lb/Ft	Trans. Lb/Ft	Total Lb/Ft	Ultimate Strength	Diam. In.	X-Area Sq.In.
ACSR Conductors														
Swanate	4	7/1	.0670	.1928	.1622	.2247	.2523	.5379	.5379	.4190	.9818	2360	.257	.0411
Sparrow	2	6/1	.0913	.2370	.1934	.2673	.2720	.5814	.5989	.4387	1.0423	2850	.316	.0608
Sparate	2	7/1	.1067	.2438	.2060	.2855	.2750	.5964	.6199	.4417	1.0611	3640	.325	.0654
Raven	1/0	6/1	.1452	.2985	.3819	.3467	.2993	.6580	.7036	.4660	1.1439	4380	.398	.0968
Quail	2/0	6/1	.1831	.3353	.4320	.3998	.3157	.7094	.7719	.4823	1.2102	5310	.447	.1221
Pigeon	3/0	6/1	.2309	.3765	.4917	.4647	.3340	.7723	.8539	.5007	1.2899	6620	.502	.1537
Penguin	4/0	6/1	.2911	.4223	.5629	.5439	.3543	.8491	.9520	.5210	1.3853	8350	.563	.1939
Waxwing	266.8	18/1	.2894	.4568	.5907	.5565	.3697	.8681	.9789	.5363	1.4162	6880	.609	.2210
Partridge	266.8	26/7	.3673	.4815	.6556	.6446	.3807	.9486	1.0774	.5473	1.5084	11300	.642	.2436
Merlin	336.4	18/1	.3653	.5130	.6798	.6557	.3947	.9653	1.1015	.5613	1.5363	8680	.684	.2789
Linnet	336.4	26/7	.4630	.5408	.7619	.7649	.4070	1.0664	1.2222	.5737	1.6501	14100	.721	.3070
Pelican	477.0	18/1	.5180	.6105	.8506	.8488	.4380	1.1551	1.3350	.6047	1.7656	11800	.814	.3955
Hawk	477.0	26/7	.6570	.6435	.9696	1.0015	.4527	1.2990	1.5014	.6193	1.9241	19500	.858	.4354
Osprey	556.5	18/1	.6040	.6593	.9441	.9550	.4597	1.2599	1.4614	.6263	1.8900	13700	.879	.4612
Dove	556.5	26/7	.7660	.6953	1.0845	1.1319	.4757	1.4278	1.6533	.6423	2.0737	22600	.927	.5083
Kingbird	636.0	18/1	.6910	.7050	1.0372	1.0610	.4800	1.3645	1.5864	.6467	2.0131	15700	.940	.5275
Grosbeak	636.0	26/7	.8750	.7425	1.1976	1.2605	.4967	1.5548	1.8014	.6633	2.2197	25200	.990	.5808
Drake	795.0	26/7	1.0940	.8310	1.4238	1.5162	.5360	1.8081	2.0938	.7027	2.5086	31500	1.108	.7264
Tern	795.0	45/7	.8960	.7973	1.2493	1.3042	.5210	1.6044	1.8678	.6877	2.2904	22100	1.063	.6674
6201 Aluminum Alloy Conductors														
Azusa	123.3	7	.1157	.2985	.3701	.3172	.2993	.6361	.6741	.4660	1.1195	4460	.398	.0968
Anaheim	155.4	7	.1459	.3353	.4156	.3626	.3157	.6807	.7347	.4823	1.1789	5390	.447	.1221
Amherst	195.7	7	.1837	.3765	.4689	.4175	.3340	.7347	.8067	.5007	1.2495	6790	.502	.1537
Alliance	246.9	7	.2318	.4223	.5317	.4846	.3543	.8003	.8927	.5210	1.3337	8560	.563	.1939
Butte	312.8	19	.2936	.4815	.6140	.5709	.3807	.8862	1.0037	.5473	1.4432	11000	.642	.2456
Canton	394.5	19	.3703	.5408	.7054	.6722	.4070	.9858	1.1295	.5737	1.5668	13300	.721	.3099
Darien	559.5	19	.5252	.6435	.8806	.8697	.4527	1.1804	1.3696	.6193	1.8031	18800	.858	.4394
Elgin	652.4	19	.6124	.6953	.9765	.9783	.4757	1.2878	1.4997	.6423	1.9314	21800	.927	.5124
Flint	740.8	37	.6754	.7433	1.0543	1.0612	.4970	1.3718	1.6025	.6637	2.0345	24400	.991	.5818
Greeley	927.2	37	.8704	.8310	1.2534	1.2926	.5360	1.5993	1.8702	.7027	2.2979	30500	1.108	.7282

TABLE B-2

NESC EXTREME WIND LOADINGS

				13 Lbs		16 Lbs		21 Lbs		26 Lbs		31 Lbs		6 Lbs	
Name	Size	Strand	Vert. Lb/Ft	Trans. Lb/Ft	Total Lb/Ft	Trans. Lb/Ft	Total Lb/Ft	Trans. Lb/Ft	Total Lb/Ft	Trans. Lb/Ft	Total Lb/Ft	Trans. Lb/Ft	Total Lb/Ft	Trans. Lb/Ft	Swing Angle
ACSR Conductors															
Swanate	4	7/1	.0670	.2784	.2864	.3427	.3492	.4498	.4547	.5568	.5608	.6639	.6673	.1285	78.35
Sparrow	2	6/1	.0913	.3423	.3543	.4213	.4311	.5530	.5605	.6847	.6907	.8163	.8214	.1580	59.98
Sparate	2	7/1	.1067	.3521	.3679	.4333	.4463	.5688	.5787	.7042	.7122	.8396	.8463	.1625	65.71
Raven	1/0	6/1	.1452	.4312	.4550	.5307	.5502	.6965	.7115	.8623	.8745	1.0282	1.0384	.1990	53.88
Quail	2/0	6/1	.1831	.4843	.5177	.5960	.6235	.7823	.8034	.9685	.9857	1.1548	1.1692	.2235	50.67
Pigeon	3/0	6/1	.2309	.5438	.5908	.6693	.7080	.8785	.9083	1.0877	1.1119	1.2968	1.3172	.2510	47.39
Penguin	4/0	6/1	.2911	.6099	.6758	.7507	.8051	.9853	1.0274	1.2198	1.2541	1.4544	1.4833	.2815	44.04
Waxwing	266.8	18/1	.2894	.6598	.7204	.8120	.8620	1.0658	1.1043	1.3195	1.3509	1.5733	1.5996	.3045	46.46
Partridge	266.8	26/7	.3673	.6955	.7865	.8560	.9315	1.1235	1.1820	1.3910	1.4387	1.6585	1.6987	.3210	41.15
Merlin	336.4	18/1	.3653	.7410	.8262	.9120	.9824	1.1970	1.2515	1.4820	1.5264	1.7670	1.8044	.3420	43.11
Linnet	336.4	26/7	.4630	.7811	.9080	.9613	1.0670	1.2618	1.3440	1.5622	1.6293	1.8626	1.9193	.3605	37.90
Pelican	477.0	18/1	.5180	.8818	1.0227	1.0853	1.2026	1.4245	1.5158	1.7637	1.8382	2.1028	2.1657	.4070	38.16
Hawk	477.0	26/7	.6570	.9295	1.1383	1.1440	1.3192	1.5015	1.6389	1.8590	1.9717	2.2165	2.3118	.4290	33.14
Osprey	556.5	18/1	.6040	.9523	1.1277	1.1720	1.3185	1.5383	1.6526	1.9045	1.9980	2.2708	2.3497	.4395	36.04
Dove	556.5	26/7	.7660	1.0043	1.2630	1.2360	1.4541	1.6223	1.7940	2.0085	2.1496	2.3948	2.5143	.4635	31.18
Kingbird	636.0	18/1	.6910	1.0183	1.2306	1.2533	1.4312	1.6450	1.7842	2.0367	2.1507	2.4283	2.5247	.4700	34.22
Grosbeak	636.0	26/7	.8750	1.0725	1.3842	1.3200	1.5837	1.7325	1.9409	2.1450	2.3166	2.5575	2.7030	.4950	29.50
Drake	795.0	26/7	1.0940	1.2003	1.6241	1.4773	1.8383	1.9390	2.2263	2.4007	2.6382	2.8623	3.0643	.5540	26.86
Tern	795.0	45/7	.8960	1.1516	1.4591	1.4173	1.6768	1.8603	2.0648	2.3032	2.4713	2.7461	2.8886	.5315	30.68
6201 Aluminum Alloy Conductors															
Azusa	123.3	7	.1157	.4312	.4464	.5307	.5431	.6965	.7060	.8623	.8701	1.0282	1.0347	.1990	59.83
Anaheim	155.4	7	.1459	.4843	.5058	.5960	.6136	.7823	.7957	.9685	.9794	1.1548	1.1639	.2235	56.86
Amherst	195.7	7	.1837	.5438	.5740	.6693	.6941	.8785	.8975	1.0877	1.1031	1.2968	1.3098	.2510	53.80
Alliance	246.9	7	.2318	.6099	.6525	.7507	.7856	.9853	1.0122	1.2198	1.2417	1.4544	1.4728	.2815	50.53
Butte	312.8	19	.2936	.6955	.7549	.8560	.9050	1.1235	1.1612	1.3910	1.4216	1.6585	1.6843	.3210	47.55
Canton	394.5	19	.3703	.7811	.8644	.9613	1.0302	1.2618	1.3150	1.5622	1.6055	1.8626	1.8990	.3605	44.23
Darien	559.5	19	.5252	.9295	1.0676	1.1440	1.2588	1.5015	1.5907	1.8590	1.9318	2.2165	2.2779	.4290	39.24
Elgin	652.4	19	.6124	1.0043	1.1762	1.2360	1.3794	1.6223	1.7340	2.0085	2.0998	2.3948	2.4718	.4635	37.12
Flint	740.8	37	.6754	1.0736	1.2684	1.3213	1.4839	1.7343	1.8611	2.1472	2.2509	2.5601	2.6477	.4955	36.27
Greeley	927.2	37	.8704	1.2003	1.4827	1.4773	1.7147	1.9390	2.1254	2.4007	2.5536	2.8623	2.9917	.5540	32.48

TABLE B-3

GUY WIRE STRENGTH DATA

TYPE STRAND	SIZE	BREAKING STRENGTH	MAXIMUM ALLOWABLE LOAD *
		lb.	lb.
Siemens Martin Steel	1/4 in.	3 150	2 835
	3/8 in.	6 950	6 255
	7/16 in.	9 350	8 415
High Strength Steel	1/4 in.	4 750	4 275
	3/8 in.	10 800	9 720
	7/16 in.	14 500	13 050
Aluminum Clad Steel	6 M	6 000	5 400
	8 M	8 000	7 200
	10 M	10 000	9 000
	12.5 M	12 500	11 250

*Breaking strength x 0.9

APPENDIX C
CONDUCTOR DESIGN DATA

The following conductor data sheets provide conductor ruling span sag and tension data, staking tables, and initial stringing sag tables to replace selected obsolete data originally provided by conductor manufacturers. Data is provided for small size ACSR conductors, No. 4 (7/1) and No. 2 (6/1) and for large sizes No. 1/0 (6/1) and No. 4/0 (6/1), these sizes and types being those most commonly used on rural distribution lines.

The sag and tension data is based on the maximum tension limits, as a percent of rated conductor strength, recommended by Table IV-5 of this design manual. The small conductor sizes are treated as conductors for use on single-phase lines, and the large sizes for use on three-phase lines.

The conductor tension for each condition of temperature and loading is given in the table of ruling span sags and tensions. The most limiting tension limit is enclosed in parentheses. The actual conductor design tension is the initial tension value for the NESC loading condition which is given in the top row of data.

The design tension value given in the upper right hand corner of each data sheet is the recommended standardized design tension for use in designing deadend assemblies and structures for use with a family of ruling span lengths. This value is sufficient to accommodate, as a minimum, the conductor design tension of the next longer ruling span provided in this set of data sheets.

The staking tables are based on NESC "other land" clearance requirements. The staking table data includes a one-foot design and construction tolerance for both ground clearance and the uplift factor.

The staking tables assume that the same conductor size and type are used for both phase and neutral conductors and the operating temperature of neither exceeds 120° F. Under these conditions the neutral conductor always controls the required ground clearance and the uplift factor is correct for both phase and neutral conductors.

The uplift factor of the staking table is based on the initial unloaded sag for the coldest temperature given in the sag and tension table.

The staking table can be used for line designs with larger size phase conductors if the phase conductor design conforms with the note at the bottom of the staking table. However, the uplift factor will be correct only if the phase conductor sag is equal to or greater than the neutral sag at the uplift condition.

When the phase and neutral conductors have different sag characteristics, it is generally advisable to prepare and use a staking table based on the sags of both conductors.

The user is cautioned that these conductor sag-tension designs may not be the most suitable for a particular system. Reduced tensions may be necessary in areas prone to aeolian vibration problems. Reduced tensions may be necessary for designs using shorter spans in order to avoid excessive uplift problems.

Conductor data sheets are provided for the following designs:

Heavy Loading District

#4 (7/1)ACSR, Ruling Spans: 325, 375, 425 ft.
#2 (6/1)ACSR, Ruling Spans: 325, 375, 425 ft.
#1/0(6/1)ACSR, Ruling Spans: 325, 375, 425 ft.
#4/0(6/1)ACSR, Ruling Spans: 300, 375, 425 ft.

Medium Loading District

#4 (7/1)ACSR, Ruling Spans: 325, 425, 525 ft.
#2 (6/1)ACSR, Ruling Spans: 325, 425, 525 ft.
#1/0(6/1)ACSR, Ruling Spans: 325, 425, 525 ft.
#4/0(6/1)ACSR, Ruling Spans: 325, 425, 525 ft.

Light Loading District

#4 (7/1)ACSR, Ruling Spans: 325, 425, 525 ft.
#2 (6/1)ACSR, Ruling Spans: 325, 425, 525 ft.
#1/0(6/1)ACSR, Ruling Spans: 325, 425, 525 ft.
#4/0(6/1)ACSR, Ruling Spans: 325, 425, 525 ft.

CONDUCTOR NO. 4 (7/1) ACSR **DESIGN RULING SPAN** 325 **FT. DESIGN TENSION** 1425 **LBS.**

RECOMMENDED FOR USE WITH RULING SPANS FROM 275 **FT. TO** 375 **FT.** HEAVY **LOADING DISTRICT**

	PHASE	NEUTRAL
CONDUCTOR DESC.	NO. 4(7/1) ACSR	NO. 4(7/1) ACSR
MAX. OPERATING TEMP.	120. DEGREES F	120. DEGREES F
BASIC GROUND CLEAR.	20.0 FEET	18.0 FEET
DESIGN TENSION	1416. LBS (60.0 %)	1416. LBS (60.0 %)

325. FOOT RULING SPAN HEAVY LOADING DISTRICT

FOR USE WITH A1,B1,AND C1 TYPE ASSEMBLIES

35.0 FOOT POLES QUARTER POINT OF SPAN	35.0 FOOT POLES CENTER OF SPAN	SPAN LENGTH	40.0 FOOT POLES CENTER OF SPAN	40.0 FOOT POLES QUARTER POINT OF SPAN	UPLIFT FACTOR
5.4	5.0	198.	10.0	10.4	0.7
5.1	4.5	219.	9.5	10.1	1.0
4.8	4.0	239.	9.0	9.8	1.4
4.5	3.5	258.	8.5	9.5	1.8
4.1	3.0	277.	8.0	9.1	2.2
3.8	2.5	294.	7.5	8.8	2.7
3.5	2.0	311.	7.0	8.5	3.1
3.1	1.5	327.	6.5	8.1	3.5
2.8	1.0	343.	6.0	7.8	4.0
2.5	0.5	358.	5.5	7.5	4.4
2.1	LEVEL 0.0	373.	5.0	7.1	4.9
1.8	-0.5	387.	4.5	6.8	5.4
1.4	-1.0	402.	4.0	6.4	5.8
1.1	-1.5	415.	3.5	6.1	6.3
0.8	-2.0	429.	3.0	5.8	6.8
0.4	-2.5	442.	2.5	5.4	7.3
0.1	-3.0	454.	2.0	5.1	7.8
-0.3	-3.5	467.	1.5	4.7	8.2
-0.6	-4.0	479.	1.0	4.4	8.7
-1.0	-4.5	491.	0.5	4.0	9.2
-1.3	-5.0	503.	LEVEL 0.0	3.7	9.7
-1.7	-5.5	515.	-0.5	3.3	10.2
-2.0	-6.0	526.	-1.0	3.0	10.7
-2.3	-6.5	537.	-1.5	2.7	11.2
-2.7	-7.0	548.	-2.0	2.3	11.8
-3.0	-7.5	559.	-2.5	2.0	12.3
-3.4	-8.0	570.	-3.0	1.6	12.8
-3.7	-8.5	581.	-3.5	1.3	13.3
-4.1	-9.0	591.	-4.0	0.9	13.8
-4.4	-9.5	601.	-4.5	0.6	14.3
-4.8	-10.0	611.	-5.0	0.2	14.9

ALL DISTANCES ARE IN FEET

TABLE INCLUDES A 1.0 FOOT STAKING AND CONSTRUCTION TOLERANCE IN ADDITION TO THE BASIC CLEARANCES
TABLE INCLUDES A 1.0 FOOT UPLIFT FACTOR TOLERANCE

THIS TABLE MAY BE USED FOR ANY PHASE CONDUCTOR WHOSE MAXIMUM TEMPERATURE IS 120 DEGREES F OR LESS, AND WHOSE 60 DEGREE F FINAL SAG IN A 325. FOOT SPAN IS LESS THAN OR EQUAL TO 3.4 FEET

STAKING TABLE

TEMP F	0	10	20	30	40	50	60	70	80	90	100
HORIZONTAL TENSION	787	754	720	687	651	615	579	542	504	467	431
SPAN FT.	STRINGING SAG-INCHES										
200	5.	5.	6.	6.	6.	7.	7.	7.	8.	9.	9.
210	6.	6.	6.	6.	7.	7.	8.	8.	9.	9.	10.
220	6.	6.	7.	7.	8.	8.	8.	9.	10.	10.	11.
230	7.	7.	7.	8.	8.	9.	9.	10.	11.	11.	13.
240	7.	8.	8.	8.	9.	9.	10.	11.	12.	12.	14.
250	8.	8.	9.	9.	10.	10.	11.	12.	13.	13.	15.
260	9.	9.	9.	10.	11.	11.	12.	13.	14.	15.	16.
270	9.	10.	10.	11.	11.	12.	13.	14.	15.	16.	17.
280	10.	10.	11.	11.	12.	13.	14.	15.	16.	17.	19.
290	11.	11.	12.	12.	13.	14.	15.	16.	17.	18.	20.
300	11.	12.	13.	13.	14.	15.	16.	17.	18.	19.	21.
310	12.	13.	13.	14.	15.	16.	17.	18.	19.	21.	23.
320	13.	14.	14.	15.	16.	17.	18.	19.	21.	22.	24.
325 RS	13.	14.	15.	15.	16.	17.	18.	20.	21.	23.	25.
330	14.	15.	15.	16.	17.	18.	19.	20.	22.	23.	26.
340	15.	15.	16.	17.	18.	19.	20.	22.	23.	25.	27.
350	16.	16.	17.	18.	19.	20.	21.	23.	25.	26.	29.
360	17.	17.	18.	19.	20.	21.	22.	24.	26.	28.	31.
370	17.	18.	19.	20.	21.	23.	24.	26.	28.	29.	32.
380	18.	19.	20.	21.	22.	24.	25.	27.	29.	31.	34.
390	19.	20.	21.	22.	24.	25.	26.	29.	31.	33.	36.
400	20.	21.	22.	23.	25.	26.	28.	30.	32.	34.	38.
410	21.	23.	24.	25.	26.	28.	29.	32.	34.	36.	40.
420	23.	24.	25.	26.	27.	29.	31.	33.	36.	38.	42.
430	24.	25.	26.	27.	29.	30.	32.	35.	37.	40.	44.

INITIAL STRINGING SAGS AND TENSIONS

DESIGN POINTS

CREEP IS NOT A FACTOR

TEMP,F	ICE,IN.	WIND,PSF	FINAL SAG, FT.	FINAL TENSION, LB.	INITIAL SAG, FT.	INITIAL TENSION, LB.
0.0	1/2	4	9.20	1416.	9.20	1416.
32.0	1/2		7.71	924.	6.68	1065.
60.0		4	4.58	314.	2.34	613.
60.0		6	5.25	365.	2.96	647.
-20.0			1.93	459.	1.04	849.
0.0			2.33	380.	1.12	(787.)
30.0			3.05	290.	1.29	687.
60.0			3.43	258.	1.53	579.
90.0			3.85	230.	1.90	467.
120.0			4.30	206.	2.47	358.
140.0			4.61	192.	3.00	295.
167.0			5.05	176.	3.84	231.
200.0			5.58	159.	4.75	187.
212.0			5.77	154.	4.94	179.

RULING SPAN SAGS AND TENSIONS

CONDUCTOR NO. 4 (7/1) ACSR **DESIGN RULING SPAN** 375 **FT.** **DESIGN TENSION** 1425 **LBS.**

RECOMMENDED FOR USE WITH RULING SPANS FROM 350 **FT. TO** 425 **FT.** HEAVY **LOADING DISTRICT**

	PHASE	NEUTRAL
CONDUCTOR DESC.	NO. 4(7/1) ACSR	NO. 4(7/1) ACSR
MAX. OPERATING TEMP.	120. DEGREES F	120.DEGREES F
BASIC GROUND CLEAR.	20.0 FEET	18.0 FEET
DESIGN TENSION	1416. LBS (60.0 %)	1416. LBS (60.0 %)

375. FOOT RULING SPAN HEAVY LOADING DISTRICT

FOR USE WITH A1,B1,AND C1 TYPE ASSEMBLIES

35.0 FOOT POLES QUARTER POINT OF SPAN	35.0 FOOT POLES CENTER OF SPAN	SPAN LENGTH	40.0 FOOT POLES CENTER OF SPAN	40.0 FOOT POLES QUARTER POINT OF SPAN	UPLIFT FACTOR
5.4	5.0	181.	10.0	10.4	1.1
5.1	4.5	200.	9.5	10.1	1.5
4.7	4.0	217.	9.0	9.7	2.0
4.4	3.5	234.	8.5	9.4	2.5
4.1	3.0	250.	8.0	9.1	2.9
3.7	2.5	265.	7.5	8.7	3.4
3.4	2.0	280.	7.0	8.4	3.9
3.0	1.5	294.	6.5	8.0	4.5
2.7	1.0	308.	6.0	7.7	5.0
2.4	0.5	321.	5.5	7.4	5.5
2.0	LEVEL 0.0	334.	5.0	7.0	6.0
1.7	-0.5	346.	4.5	6.7	6.6
1.3	-1.0	358.	4.0	6.3	7.1
1.0	-1.5	370.	3.5	6.0	7.7
0.6	-2.0	382.	3.0	5.6	8.2
0.3	-2.5	393.	2.5	5.3	8.8
-0.1	-3.0	404.	2.0	4.9	9.3
-0.4	-3.5	415.	1.5	4.6	9.9
-0.7	-4.0	426.	1.0	4.3	10.4
-1.1	-4.5	436.	0.5	3.9	11.0
-1.4	-5.0	446.	LEVEL 0.0	3.6	11.6
-1.8	-5.5	456.	-0.5	3.2	12.2
-2.1	-6.0	466.	-1.0	2.9	12.7
-2.5	-6.5	476.	-1.5	2.5	13.3
-2.8	-7.0	486.	-2.0	2.2	13.9
-3.2	-7.5	495.	-2.5	1.8	14.5
-3.6	-8.0	504.	-3.0	1.4	15.1
-3.9	-8.5	513.	-3.5	1.1	15.6
-4.3	-9.0	522.	-4.0	0.7	16.2
-4.6	-9.5	531.	-4.5	0.4	16.8
-5.0	-10.0	540.	-5.0	0.0	17.4

ALL DISTANCES ARE IN FEET

TABLE INCLUDES A 1.0 FOOT STAKING AND CONSTRUCTION TOLERANCE IN ADDITION TO THE BASIC CLEARANCES
TABLE INCLUDES A 1.0 FOOT UPLIFT FACTOR TOLERANCE

THIS TABLE MAY BE USED FOR ANY PHASE CONDUCTOR WHOSE MAXIMUM TEMPERATURE IS 120 DEGREES F OR LESS, AND WHOSE 60 DEGREE F FINAL SAG IN A 375. FOOT SPAN IS LESS THAN OR EQUAL TO 6.2 FEET

STAKING TABLE

TEMP F	0	10	20	30	40	50	60	70	80	90	100
HORIZONTAL TENSION	530	496	462	428	397	366	335	311	287	263	246
SPAN FT.				STRINGING SAG-INCHES							
250	12.	13.	14.	15.	16.	17.	19.	20.	22.	24.	26.
260	13.	14.	15.	16.	17.	19.	20.	22.	24.	26.	28.
270	14.	15.	16.	17.	19.	20.	22.	24.	26.	28.	30.
280	15.	16.	17.	18.	20.	22.	24.	26.	28.	30.	32.
290	16.	17.	18.	20.	22.	23.	25.	28.	30.	32.	35.
300	17.	18.	20.	21.	23.	25.	27.	29.	32.	34.	37.
310	18.	20.	21.	23.	25.	27.	29.	31.	34.	37.	40.
320	19.	21.	23.	24.	26.	29.	31.	34.	36.	39.	42.
330	21.	22.	24.	26.	28.	30.	33.	36.	39.	42.	45.
340	22.	24.	25.	27.	30.	32.	35.	38.	41.	44.	48.
350	23.	25.	27.	29.	31.	34.	37.	40.	43.	47.	51.
360	25.	27.	28.	30.	33.	36.	39.	42.	46.	50.	53.
370	26.	28.	30.	32.	35.	38.	41.	45.	49.	52.	56.
375 RS	27.	29.	31.	33.	36.	39.	42.	46.	50.	54.	58.
380	27.	30.	32.	34.	37.	40.	43.	47.	51.	55.	60.
390	29.	31.	33.	36.	39.	42.	46.	50.	54.	58.	63.
400	30.	33.	35.	38.	41.	45.	48.	52.	57.	61.	66.
410	32.	34.	37.	39.	43.	47.	50.	55.	60.	64.	69.
420	33.	36.	39.	41.	45.	49.	53.	58.	63.	67.	73.
430	35.	38.	41.	43.	47.	51.	55.	61.	66.	71.	76.
440	37.	40.	43.	45.	50.	54.	58.	63.	69.	74.	80.
450	38.	41.	45.	48.	52.	56.	61.	66.	72.	77.	84.
460	40.	43.	47.	50.	54.	59.	64.	69.	75.	81.	87.
470	42.	45.	49.	52.	57.	61.	66.	72.	78.	84.	91.
480	44.	47.	51.	54.	59.	64.	69.	75.	82.	88.	95.
490	46.	49.	53.	56.	62.	67.	72.	79.	85.	92.	99.
500	47.	51.	55.	59.	64.	70.	75.	82.	89.	96.	103.

INITIAL STRINGING SAGS AND TENSIONS

DESIGN POINTS

CREEP IS NOT A FACTOR

TEMP,F	ICE,IN.	WIND,PSF	FINAL SAG, FT.	FINAL TENSION, LB.	INITIAL SAG, FT.	INITIAL TENSION, LB.
0.0	1/2	4	12.26	1416.	12.26	(1416.)
32.0	1/2		10.65	892.	9.39	1011.
60.0		4	7.34	261.	4.61	415.
60.0		6	8.10	315.	5.33	478.
-20.0			4.64	254.	1.97	598.
0.0			5.15	229.	2.22	530.
30.0			5.67	208.	2.75	428.
60.0			6.20	190.	3.51	335.
90.0			6.73	175.	4.48	263.
120.0			7.26	163.	5.53	213.
140.0			7.61	155.	6.23	189.
167.0			8.07	146.	7.13	166.
200.0			8.61	137.	7.74	153.
212.0			8.81	134.	7.94	149.

RULING SPAN SAGS AND TENSIONS

CONDUCTOR NO. 4 (7/1) ACSR DESIGN RULING SPAN 425 FT. DESIGN TENSION 1425 LBS.

RECOMMENDED FOR USE WITH RULING SPANS FROM 400 FT. TO 475 FT. HEAVY LOADING DISTRICT

	PHASE	NEUTRAL
CONDUCTOR DESC.	NO. 4(7/1) ACSR	NO. 4(7/1) ACSR
MAX. OPERATING TEMP.	120. DEGREES F	120. DEGREES F
BASIC GROUND CLEAR.	20.0 FEET	18.0 FEET
DESIGN TENSION	1416. LBS (60.0 %)	1416. LBS (60.0 %)

425. FOOT RULING SPAN HEAVY LOADING DISTRICT

FOR USE WITH A1,B1,AND C1 TYPE ASSEMBLIES

35.0 FOOT POLES QUARTER POINT OF SPAN	35.0 FOOT POLES CENTER OF SPAN	SPAN LENGTH	40.0 FOOT POLES CENTER OF SPAN	40.0 FOOT POLES QUARTER POINT OF SPAN	UPLIFT FACTOR
5.4	5.0	167.	10.0	10.4	2.2
5.0	4.5	187.	9.5	10.0	3.0
4.7	4.0	203.	9.0	9.7	3.7
4.4	3.5	218.	8.5	9.4	4.4
4.0	3.0	233.	8.0	9.0	5.2
3.7	2.5	247.	7.5	8.7	5.9
3.3	2.0	260.	7.0	8.3	6.7
3.0	1.5	273.	6.5	8.0	7.5
2.7	1.0	285.	6.0	7.7	8.3
2.3	0.5	297.	5.5	7.3	9.1
2.0	LEVEL 0.0	309.	5.0	7.0	9.9
1.6	-0.5	320.	4.5	6.6	10.7
1.3	-1.0	331.	4.0	6.3	11.5
0.9	-1.5	342.	3.5	5.9	12.3
0.6	-2.0	353.	3.0	5.6	13.2
0.2	-2.5	363.	2.5	5.2	14.0
-0.1	-3.0	373.	2.0	4.9	14.8
-0.5	-3.5	383.	1.5	4.5	15.7
-0.8	-4.0	393.	1.0	4.2	16.5
-1.2	-4.5	402.	0.5	3.8	17.4
-1.5	-5.0	411.	LEVEL 0.0	3.5	18.2
-1.9	-5.5	420.	-0.5	3.1	19.1
-2.2	-6.0	429.	-1.0	2.8	20.0
-2.6	-6.5	438.	-1.5	2.4	20.8
-2.9	-7.0	447.	-2.0	2.1	21.7
-3.3	-7.5	455.	-2.5	1.7	22.6
-3.7	-8.0	464.	-3.0	1.3	23.5
-4.0	-8.5	472.	-3.5	1.0	24.3
-4.4	-9.0	480.	-4.0	0.6	25.2
-4.7	-9.5	488.	-4.5	0.3	26.1
-5.1	-10.0	496.	-5.0	-0.1	27.0

ALL DISTANCES ARE IN FEET

TABLE INCLUDES A 1.0 FOOT STAKING AND CONSTRUCTION TOLERANCE IN ADDITION TO THE BASIC CLEARANCES
TABLE INCLUDES A 1.0 FOOT UPLIFT FACTOR TOLERANCE

THIS TABLE MAY BE USED FOR ANY PHASE CONDUCTOR WHOSE MAXIMUM TEMPERATURE IS 120 DEGREES F OR LESS, AND WHOSE 60 DEGREE F FINAL SAG IN A 425. FOOT SPAN IS LESS THAN OR EQUAL TO 9.8 FEET

STAKING TABLE

TEMP F	0	10	20	30	40	50	60	70	80	90	100
HORIZONTAL TENSION	294	277	260	243	230	218	206	197	189	181	174
SPAN FT.	STRINGING SAG-INCHES										
350	42.	45.	48.	51.	54.	57.	60.	63.	65.	68.	71.
360	44.	47.	51.	54.	57.	60.	63.	66.	69.	72.	75.
370	47.	50.	53.	57.	60.	63.	67.	70.	73.	76.	79.
380	49.	53.	56.	60.	63.	67.	71.	74.	77.	80.	84.
390	52.	56.	59.	63.	67.	71.	74.	78.	81.	85.	88.
400	55.	59.	62.	66.	70.	74.	78.	82.	85.	89.	93.
410	58.	62.	66.	70.	74.	78.	82.	86.	90.	94.	97.
420	60.	65.	69.	73.	77.	82.	86.	90.	94.	98.	102.
425 RS	62.	66.	70.	75.	79.	84.	88.	92.	96.	100.	105.
430	63.	68.	72.	77.	81.	86.	90.	95.	99.	103.	107.
440	66.	71.	76.	80.	85.	90.	95.	99.	103.	108.	112.
450	69.	74.	79.	84.	89.	94.	99.	104.	109.	113.	117.
460	72.	77.	83.	88.	93.	98.	103.	108.	113.	118.	123.
470	76.	81.	86.	91.	97.	102.	108.	113.	118.	123.	128.
480	79.	84.	90.	95.	101.	107.	113.	118.	123.	128.	134.
490	82.	88.	94.	99.	105.	111.	117.	123.	128.	134.	139.
500	86.	92.	98.	104.	110.	116.	122.	128.	133.	139.	145.
510	89.	95.	101.	108.	114.	121.	127.	133.	139.	145.	151.
520	93.	99.	105.	112.	119.	125.	132.	138.	144.	150.	157.

INITIAL STRINGING SAGS AND TENSIONS

DESIGN POINTS

CREEP IS NOT A FACTOR

TEMP,F	ICE,IN.	WIND,PSF	FINAL SAG, FT.	FINAL TENSION, LB.	INITIAL SAG, FT.	INITIAL TENSION, LB.
0.0	1/2	4	15.77	1416.	15.77	(1416.)
32.0	1/2		14.08	868.	12.63	966.
60.0		4	10.76	229.	8.16	301.
60.0		6	11.48	286.	8.76	374.
-20.0			8.26	183.	4.46	339.
0.0			8.64	175.	5.14	294.
30.0			9.21	165.	6.24	243.
60.0			9.76	155.	7.34	206.
90.0			10.29	147.	8.40	181.
120.0			10.82	140.	9.40	161.
140.0			11.16	136.	10.03	151.
167.0			11.61	131.	10.72	142.
200.0			12.15	125.	11.28	135.
212.0			12.34	123.	11.48	132.

RULING SPAN SAGS AND TENSIONS

CONDUCTOR NO. 2 (6/1/) ACSR DESIGN RULING SPAN 325 FT. DESIGN TENSION 1725 LBS.

RECOMMENDED FOR USE WITH RULING SPANS FROM 275 FT. TO 375 FT. HEAVY LOADING DISTRICT

	PHASE	NEUTRAL
CONDUCTOR DESC.	NO. 2(6/1) ACSR	NO. 2(6/1) ACSR
MAX. OPERATING TEMP.	120. DEGREES F	120.DEGREES F
BASIC GROUND CLEAR.	20.0 FEET	18.0 FEET
DESIGN TENSION	1664. LBS (58.4 %)	1664. LBS (58.4 %)

325. FOOT RULING SPAN HEAVY LOADING DISTRICT

FOR USE WITH A1,B1,AND C1 TYPE ASSEMBLIES

35.0 FOOT POLES QUARTER POINT OF SPAN	35.0 FOOT POLES CENTER OF SPAN	SPAN LENGTH	40.0 FOOT POLES CENTER OF SPAN	40.0 FOOT POLES QUARTER POINT OF SPAN	UPLIFT FACTOR
5.4	5.0	191.	10.0	10.4	0.7
5.1	4.5	211.	9.5	10.1	1.1
4.8	4.0	230.	9.0	9.8	1.5
4.4	3.5	248.	8.5	9.4	2.0
4.1	3.0	265.	8.0	9.1	2.4
3.8	2.5	282.	7.5	8.8	2.8
3.4	2.0	298.	7.0	8.4	3.3
3.1	1.5	313.	6.5	8.1	3.7
2.8	1.0	328.	6.0	7.8	4.2
2.4	0.5	342.	5.5	7.4	4.6
2.1	LEVEL 0.0	356.	5.0	7.1	5.1
1.7	-0.5	370.	4.5	6.7	5.6
1.4	-1.0	383.	4.0	6.4	6.1
1.1	-1.5	396.	3.5	6.1	6.5
0.7	-2.0	409.	3.0	5.7	7.0
0.4	-2.5	421.	2.5	5.4	7.5
0.0	-3.0	433.	2.0	5.0	8.0
-0.3	-3.5	445.	1.5	4.7	8.5
-0.7	-4.0	456.	1.0	4.3	9.0
-1.0	-4.5	468.	0.5	4.0	9.5
-1.4	-5.0	479.	LEVEL 0.0	3.6	10.0
-1.7	-5.5	490.	-0.5	3.3	10.5
-2.1	-6.0	500.	-1.0	2.9	11.0
-2.4	-6.5	511.	-1.5	2.6	11.6
-2.8	-7.0	521.	-2.0	2.2	12.1
-3.1	-7.5	532.	-2.5	1.9	12.6
-3.5	-8.0	542.	-3.0	1.5	13.1
-3.8	-8.5	552.	-3.5	1.2	13.6
-4.2	-9.0	561.	-4.0	0.8	14.2
-4.5	-9.5	571.	-4.5	0.5	14.7
-4.9	-10.0	581.	-5.0	0.1	15.2

ALL DISTANCES ARE IN FEET

TABLE INCLUDES A 1.0 FOOT STAKING AND CONSTRUCTION TOLERANCE IN ADDITION TO THE BASIC CLEARANCES
TABLE INCLUDES A 1.0 FOOT UPLIFT FACTOR TOLERANCE

THIS TABLE MAY BE USED FOR ANY PHASE CONDUCTOR WHOSE MAXIMUM TEMPERATURE IS 120 DEGREES F OR LESS, AND WHOSE 60 DEGREE F FINAL SAG IN A 325. FOOT SPAN IS LESS THAN OR EQUAL TO 3.9 FEET

STAKING TABLE

TEMP F	0	10	20	30	40	50	60	70	80	90	100
HORIZONTAL TENSION	950	903	855	808	758	709	659	610	561	512	470
SPAN FT.	STRINGING SAG-INCHES										
200	6.	6.	6.	7.	7.	8.	8.	9.	10.	11.	12.
210	6.	7.	7.	7.	8.	9.	9.	10.	11.	12.	13.
220	7.	7.	8.	8.	9.	9.	10.	11.	12.	13.	14.
230	8.	8.	9.	9.	10.	10.	11.	12.	13.	14.	16.
240	8.	9.	9.	10.	10.	11.	12.	13.	14.	15.	17.
250	9.	10.	10.	11.	11.	12.	13.	14.	15.	17.	19.
260	10.	10.	11.	11.	12.	13.	14.	15.	17.	18.	20.
270	11.	11.	12.	12.	13.	14.	15.	17.	18.	20.	22.
280	11.	12.	13.	13.	14.	15.	16.	18.	19.	21.	23.
290	12.	13.	14.	14.	15.	16.	17.	19.	21.	23.	25.
300	13.	14.	14.	15.	16.	18.	19.	20.	22.	24.	27.
310	14.	15.	15.	16.	18.	19.	20.	22.	24.	26.	29.
320	15.	16.	16.	17.	19.	20.	21.	23.	25.	27.	30.
325 RS	15.	16.	17.	18.	19.	21.	22.	24.	26.	28.	31.
330	16.	17.	18.	18.	20.	21.	23.	25.	27.	29.	32.
340	17.	18.	19.	20.	21.	23.	24.	26.	29.	31.	34.
350	18.	19.	20.	21.	22.	24.	25.	28.	30.	33.	36.
360	19.	20.	21.	22.	24.	25.	27.	30.	32.	35.	38.
370	20.	21.	22.	23.	25.	27.	28.	31.	34.	37.	41.
380	21.	22.	23.	24.	26.	28.	30.	33.	36.	39.	43.
390	22.	23.	24.	26.	28.	30.	32.	35.	38.	41.	45.
400	23.	24.	26.	27.	29.	31.	33.	36.	40.	43.	48.
410	24.	26.	27.	28.	31.	33.	35.	38.	42.	45.	50.
420	25.	27.	28.	30.	32.	34.	37.	40.	44.	47.	52.
430	27.	28.	30.	31.	34.	36.	38.	42.	46.	49.	55.

INITIAL STRINGING SAGS AND TENSIONS

DESIGN POINTS
CREEP IS NOT A FACTOR

TEMP,F	ICE,IN.	WIND,PSF	FINAL SAG, FT.	FINAL TENSION, LB.	INITIAL SAG, FT.	INITIAL TENSION, LB.
0.0	1/2	4	8.30	1664.	8.30	1664.
32.0	1/2		7.14	1110.	6.29	1259.
60.0		4	4.71	391.	2.60	708.
60.0		6	5.15	468.	3.19	756.
-20.0			1.85	651.	1.16	1039.
0.0			2.26	533.	1.27	(950.)
30.0			3.10	389.	1.49	808.
60.0			3.90	310.	1.83	659.
90.0			4.28	282.	2.35	512.
120.0			4.70	257.	3.13	385.
140.0			4.98	242.	3.77	320.
167.0			5.37	225.	4.67	258.
200.0			5.85	206.	5.68	213.
212.0			6.03	200.	5.85	206.

RULING SPAN SAGS AND TENSIONS

CONDUCTOR NO. 2 (6/1) ACSR **DESIGN RULING SPAN** 375 **FT. DESIGN TENSION** 1725 **LBS.**

RECOMMENDED FOR USE WITH RULING SPANS FROM 350 **FT. TO** 425 **FT.** HEAVY **LOADING DISTRICT**

	PHASE	NEUTRAL
CONDUCTOR DESC.	NO. 2(6/1) ACSR	NO. 2(6/1) ACSR
MAX. OPERATING TEMP.	120. DEGREES F	120.DEGREES F
BASIC GROUND CLEAR.	20.0 FEET	18.0 FEET
DESIGN TENSION	1710. LBS (60.0 %)	1710. LBS (60.0 %)

375. FOOT RULING SPAN HEAVY LOADING DISTRICT

FOR USE WITH A1,B1,AND C1 TYPE ASSEMBLIES

35.0 FOOT POLES QUARTER POINT OF SPAN	35.0 FOOT POLES CENTER OF SPAN	SPAN LENGTH	40.0 FOOT POLES CENTER OF SPAN	40.0 FOOT POLES QUARTER POINT OF SPAN	UPLIFT FACTOR
5.4	5.0	186.	10.0	10.4	1.0
5.1	4.5	205.	9.5	10.1	1.4
4.7	4.0	223.	9.0	9.7	1.8
4.4	3.5	241.	8.5	9.4	2.3
4.1	3.0	257.	8.0	9.1	2.8
3.7	2.5	273.	7.5	8.7	3.2
3.4	2.0	288.	7.0	8.4	3.7
3.1	1.5	303.	6.5	8.1	4.2
2.7	1.0	317.	6.0	7.7	4.7
2.4	0.5	331.	5.5	7.4	5.2
2.0	LEVEL 0.0	345.	5.0	7.0	5.8
1.7	-0.5	358.	4.5	6.7	6.3
1.4	-1.0	370.	4.0	6.4	6.8
1.0	-1.5	383.	3.5	6.0	7.3
0.7	-2.0	395.	3.0	5.7	7.9
0.3	-2.5	406.	2.5	5.3	8.4
0.0	-3.0	418.	2.0	5.0	8.9
-0.4	-3.5	429.	1.5	4.6	9.5
-0.7	-4.0	440.	1.0	4.3	10.0
-1.1	-4.5	451.	0.5	3.9	10.6
-1.4	-5.0	462.	LEVEL 0.0	3.6	11.1
-1.8	-5.5	472.	-0.5	3.2	11.7
-2.1	-6.0	483.	-1.0	2.9	12.2
-2.5	-6.5	493.	-1.5	2.5	12.8
-2.8	-7.0	503.	-2.0	2.2	13.4
-3.2	-7.5	512.	-2.5	1.8	13.9
-3.5	-8.0	522.	-3.0	1.5	14.5
-3.9	-8.5	532.	-3.5	1.1	15.1
-4.2	-9.0	541.	-4.0	0.8	15.6
-4.6	-9.5	550.	-4.5	0.4	16.2
-4.9	-10.0	559.	-5.0	0.1	16.8

ALL DISTANCES ARE IN FEET

TABLE INCLUDES A 1.0 FOOT STAKING AND CONSTRUCTION TOLERANCE IN ADDITION TO THE BASIC CLEARANCES
TABLE INCLUDES A 1.0 FOOT UPLIFT FACTOR TOLERANCE

THIS TABLE MAY BE USED FOR ANY PHASE CONDUCTOR WHOSE MAXIMUM TEMPERATURE IS 120 DEGREES F OR LESS, AND WHOSE 60 DEGREE F FINAL SAG IN A 375. FOOT SPAN IS LESS THAN OR EQUAL TO 5.7 FEET

STAKING TABLE

TEMP F	0	10	20	30	40	50	60	70	80	90	100
HORIZONTAL TENSION	804	757	710	663	617	572	526	487	447	408	379
SPAN FT.	STRINGING SAG-INCHES										
250	11.	11.	12.	13.	14.	15.	16.	18.	19.	21.	23.
260	12.	12.	13.	14.	15.	16.	18.	19.	21.	23.	25.
270	12.	13.	14.	15.	16.	18.	19.	21.	23.	24.	27.
280	13.	14.	15.	16.	18.	19.	20.	22.	24.	26.	29.
290	14.	15.	16.	17.	19.	20.	22.	24.	26.	28.	31.
300	15.	16.	18.	19.	20.	22.	23.	26.	28.	30.	33.
310	16.	18.	19.	20.	22.	23.	25.	27.	30.	32.	35.
320	17.	19.	20.	21.	23.	25.	27.	29.	32.	34.	37.
330	19.	20.	21.	22.	24.	26.	28.	31.	34.	37.	40.
340	20.	21.	22.	24.	26.	28.	30.	33.	36.	39.	42.
350	21.	22.	24.	25.	28.	30.	32.	35.	38.	41.	45.
360	22.	24.	25.	27.	29.	31.	34.	37.	40.	44.	47.
370	23.	25.	27.	28.	31.	33.	36.	39.	43.	46.	50.
375 RS	24.	26.	27.	29.	32.	34.	37.	40.	44.	47.	51.
380	25.	26.	28.	30.	32.	35.	38.	41.	45.	48.	53.
390	26.	28.	30.	31.	34.	37.	40.	43.	47.	51.	56.
400	27.	29.	31.	33.	36.	39.	42.	46.	50.	54.	59.
410	29.	31.	33.	35.	38.	41.	44.	48.	52.	56.	61.
420	30.	32.	34.	36.	40.	43.	46.	50.	55.	59.	65.
430	32.	34.	36.	38.	42.	45.	48.	53.	57.	62.	68.
440	33.	35.	38.	40.	43.	47.	50.	55.	60.	65.	71.
450	34.	37.	39.	42.	45.	49.	53.	58.	63.	68.	74.
460	36.	39.	41.	44.	48.	51.	55.	60.	66.	71.	77.
470	38.	40.	43.	46.	50.	54.	58.	63.	69.	74.	81.
480	39.	42.	45.	48.	52.	56.	60.	66.	72.	77.	84.
490	41.	44.	47.	50.	54.	58.	63.	69.	75.	81.	88.
500	43.	46.	49.	52.	56.	61.	65.	71.	78.	84.	91.

INITIAL STRINGING SAGS AND TENSIONS

DESIGN POINTS
CREEP IS NOT A FACTOR

TEMP,F	ICE,IN.	WIND,PSF	FINAL SAG, FT.	FINAL TENSION, LB.	INITIAL SAG, FT.	INITIAL TENSION, LB.
0.0	1/2	4	10.76	1710.	10.76	(1710.)
32.0	1/2		9.44	1118.	8.37	1261.
60.0		4	6.90	356.	4.05	605.
60.0		6	7.33	438.	4.77	673.
-20.0			3.41	470.	1.79	896.
0.0			4.11	391.	2.00	804.
30.0			5.22	308.	2.42	663.
60.0			5.69	283.	3.05	526.
90.0			6.16	261.	3.93	408.
120.0			6.64	242.	4.99	322.
140.0			6.96	231.	5.72	281.
167.0			7.39	217.	6.69	240.
200.0			7.92	203.	7.69	209.
212.0			8.11	198.	7.88	204.

RULING SPAN SAGS AND TENSIONS

CONDUCTOR NO. 2 (6/1) ACSR **DESIGN RULING SPAN** 425 **FT.** **DESIGN TENSION** 1725 **LBS.**

RECOMMENDED FOR USE WITH RULING SPANS FROM 400 **FT. TO** 475 **FT.** HEAVY **LOADING DISTRICT**

	PHASE	NEUTRAL
CONDUCTOR DESC.	NO. 2(6/1) ACSR	NO. 2(6/1) ACSR
MAX. OPERATING TEMP.	120. DEGREES F	120.DEGREES F
BASIC GROUND CLEAR.	20.0 FEET	18.0 FEET
DESIGN TENSION	1710 LBS (60.0 %)	1710 LBS (60.0 %)

425. FOOT RULING SPAN HEAVY LOADING DISTRICT

FOR USE WITH A1,B1,AND C1 TYPE ASSEMBLIES

35.0 FOOT POLES QUARTER POINT OF SPAN	35.0 FOOT POLES CENTER OF SPAN	SPAN LENGTH	40.0 FOOT POLES CENTER OF SPAN	40.0 FOOT POLES QUARTER POINT OF SPAN	UPLIFT FACTOR
5.4	5.0	177.	10.0	10.4	1.6
5.1	4.5	195.	9.5	10.1	2.2
4.7	4.0	212.	9.0	9.7	2.8
4.4	3.5	228.	8.5	9.4	3.4
4.0	3.0	244.	8.0	9.0	4.0
3.7	2.5	259.	7.5	8.7	4.7
3.4	2.0	273.	7.0	8.4	5.3
3.0	1.5	286.	6.5	8.0	5.9
2.7	1.0	300.	6.0	7.7	6.6
2.3	0.5	313.	5.5	7.3	7.3
2.0	LEVEL 0.0	325.	5.0	7.0	7.9
1.7	-0.5	337.	4.5	6.7	8.6
1.3	-1.0	349.	4.0	6.3	9.3
1.0	-1.5	360.	3.5	6.0	10.0
0.6	-2.0	372.	3.0	5.6	10.7
0.3	-2.5	382.	2.5	5.3	11.4
-0.1	-3.0	393.	2.0	4.9	12.1
-0.4	-3.5	404.	1.5	4.6	12.8
-0.8	-4.0	414.	1.0	4.2	13.5
-1.1	-4.5	424.	0.5	3.9	14.2
-1.5	-5.0	434.	LEVEL 0.0	3.5	14.9
-1.8	-5.5	444.	-0.5	3.2	15.6
-2.2	-6.0	453.	-1.0	2.8	16.4
-2.5	-6.5	462.	-1.5	2.5	17.1
-2.9	-7.0	472.	-2.0	2.1	17.8
-3.2	-7.5	481.	-2.5	1.8	18.6
-3.6	-8.0	490.	-3.0	1.4	19.3
-3.9	-8.5	499.	-3.5	1.1	20.0
-4.3	-9.0	507.	-4.0	0.7	20.8
-4.6	-9.5	516.	-4.5	0.4	21.5
-5.0	-10.0	524.	-5.0	0.0	22.2

ALL DISTANCES ARE IN FEET

TABLE INCLUDES A 1.0 FOOT STAKING AND CONSTRUCTION TOLERANCE IN ADDITION TO THE BASIC CLEARANCES
TABLE INCLUDES A 1.0 FOOT UPLIFT FACTOR TOLERANCE

THIS TABLE MAY BE USED FOR ANY PHASE CONDUCTOR WHOSE MAXIMUM TEMPERATURE IS 120 DEGREES F OR LESS, AND WHOSE 60 DEGREE F FINAL SAG IN A 425. FOOT SPAN IS LESS THAN OR EQUAL TO 8.6 FEET

STAKING TABLE

TEMP F	0	10	20	30	40	50	60	70	80	90	100
HORIZONTAL TENSION	539	503	467	431	403	376	349	330	311	292	278
SPAN FT.	STRINGING SAG-INCHES										
350	31.	34.	36.	39.	42.	45.	48.	51.	54.	58.	61.
360	33.	36.	38.	41.	44.	48.	51.	54.	58.	61.	64.
370	35.	38.	41.	44.	47.	50.	54.	57.	61.	64.	68.
380	37.	40.	43.	46.	50.	53.	57.	60.	64.	68.	72.
390	39.	42.	45.	48.	52.	56.	60.	64.	68.	71.	75.
400	41.	44.	47.	51.	55.	59.	63.	67.	71.	75.	79.
410	43.	46.	50.	53.	58.	62.	66.	70.	75.	79.	83.
420	45.	49.	52.	56.	60.	65.	69.	74.	78.	83.	87.
425 RS	46.	50.	54.	57.	62.	66.	71.	76.	80.	85.	89.
430	47.	51.	55.	59.	63.	68.	73.	77.	82.	87.	92.
440	49.	53.	57.	62.	66.	71.	76.	81.	86.	91.	96.
450	51.	56.	60.	64.	69.	74.	80.	85.	90.	95.	100.
460	54.	58.	63.	67.	73.	78.	83.	89.	94.	99.	105.
470	56.	61.	66.	70.	76.	81.	87.	92.	98.	104.	109.
480	59.	63.	68.	73.	79.	85.	91.	96.	102.	108.	114.
490	61.	66.	71.	76.	82.	88.	94.	100.	107.	113.	119.
500	64.	69.	74.	79.	86.	92.	98.	105.	111.	117.	124.
510	66.	72.	77.	83.	89.	96.	102.	109.	116.	122.	129.
520	69.	74.	80.	86.	93.	99.	106.	113.	120.	127.	134.

INITIAL STRINGING SAGS AND TENSIONS

DESIGN POINTS
CREEP IS NOT A FACTOR

TEMP,F	ICE,IN.	WIND,PSF	FINAL SAG, FT.	FINAL TENSION, LB.	INITIAL SAG, FT.	INITIAL TENSION, LB.
0.0	1/2	4	13.84	1710.	13.84	(1710.)
32.0	1/2		12.44	1092.	11.20	1212.
60.0		4	9.76	323.	6.86	459.
60.0		6	10.39	398.	7.55	517.
-20.0			6.54	316.	3.32	622.
0.0			7.33	282.	3.82	539.
30.0			8.02	257.	4.78	431.
60.0			8.55	242.	5.91	349.
90.0			9.07	228.	7.08	292.
120.0			9.59	215.	8.21	251.
140.0			9.93	208.	8.93	231.
167.0			10.39	199.	9.86	210.
200.0			10.94	189.	10.69	194.
212.0			11.13	186.	10.88	190.

RULING SPAN SAGS AND TENSIONS

CONDUCTOR 1/0 (6/1) ACSR DESIGN RULING SPAN 325 FT. DESIGN TENSION 2200 LBS.

RECOMMENDED FOR USE WITH RULING SPANS FROM 275 FT. TO 375 FT. HEAVY LOADING DISTRICT

	PHASE	NEUTRAL
CONDUCTOR DESC.	1/0 (6/1) ACSR	1/0 (6/1) ACSR
MAX. OPERATING TEMP.	120. DEGREES F	120.DEGREES F
BASIC GROUND CLEAR.	20.0 FEET	18.0 FEET
DESIGN TENSION	2190. LBS (50.0 %)	2190. LBS (50.0 %)

325. FOOT RULING SPAN HEAVY LOADING DISTRICT

FOR USE WITH A1,B1,AND C1 TYPE ASSEMBLIES

35.0 FOOT POLES QUARTER POINT OF SPAN	35.0 FOOT POLES CENTER OF SPAN	SPAN LENGTH	40.0 FOOT POLES CENTER OF SPAN	40.0 FOOT POLES QUARTER POINT OF SPAN	UPLIFT FACTOR
5.4	5.0	195.	10.0	10.4	1.0
5.1	4.5	216.	9.5	10.1	1.4
4.8	4.0	235.	9.0	9.8	1.9
4.4	3.5	254.	8.5	9.4	2.3
4.1	3.0	272.	8.0	9.1	2.8
3.8	2.5	289.	7.5	8.8	3.3
3.5	2.0	306.	7.0	8.5	3.8
3.1	1.5	322.	6.5	8.1	4.3
2.8	1.0	337.	6.0	7.8	4.8
2.4	0.5	352.	5.5	7.4	5.4
2.1	LEVEL 0.0	366.	5.0	7.1	5.9
1.8	-0.5	380.	4.5	6.8	6.5
1.4	-1.0	394.	4.0	6.4	7.0
1.1	-1.5	407.	3.5	6.1	7.6
0.7	-2.0	421.	3.0	5.7	8.1
0.4	-2.5	433.	2.5	5.4	8.7
0.1	-3.0	446.	2.0	5.1	9.2
-0.3	-3.5	458.	1.5	4.7	9.8
-0.6	-4.0	470.	1.0	4.4	10.4
-1.0	-4.5	482.	0.5	4.0	11.0
-1.3	-5.0	493.	LEVEL 0.0	3.7	11.5
-1.7	-5.5	505.	-0.5	3.3	12.1
-2.0	-6.0	516.	-1.0	3.0	12.7
-2.4	-6.5	527.	-1.5	2.6	13.3
-2.7	-7.0	538.	-2.0	2.3	13.9
-3.1	-7.5	548.	-2.5	1.9	14.5
-3.4	-8.0	559.	-3.0	1.6	15.1
-3.8	-8.5	569.	-3.5	1.2	15.7
-4.1	-9.0	579.	-4.0	0.9	16.3
-4.5	-9.5	589.	-4.5	0.5	16.9
-4.8	-10.0	599.	-5.0	0.2	17.5

ALL DISTANCES ARE IN FEET

TABLE INCLUDES A 1.0 FOOT STAKING AND CONSTRUCTION TOLERANCE IN ADDITION TO THE BASIC CLEARANCES
TABLE INCLUDES A 1.0 FOOT UPLIFT FACTOR TOLERANCE

THIS TABLE MAY BE USED FOR ANY PHASE CONDUCTOR WHOSE MAXIMUM TEMPERATURE IS 120 DEGREES F OR LESS, AND WHOSE 60 DEGREE F FINAL SAG IN A 325. FOOT SPAN IS LESS THAN OR EQUAL TO 3.6 FEET

STAKING TABLE

TEMP F	0	10	20	30	40	50	60	70	80	90	100
HORIZONTAL TENSION	1411	1342	1272	1203	1132	1060	989	920	852	783	723
SPAN FT.	STRINGING SAG-INCHES										
200	6.	7.	7.	7.	8.	8.	9.	10.	10.	11.	12.
210	7.	7.	8.	8.	9.	9.	10.	11.	11.	12.	13.
220	7.	8.	8.	9.	9.	10.	11.	12.	13.	13.	15.
230	8.	9.	9.	10.	10.	11.	12.	13.	14.	15.	16.
240	9.	9.	10.	10.	11.	12.	13.	14.	15.	16.	18.
250	10.	10.	11.	11.	12.	13.	14.	15.	16.	17.	19.
260	10.	11.	12.	12.	13.	14.	15.	16.	18.	19.	21.
270	11.	12.	13.	13.	14.	15.	16.	17.	19.	20.	22.
280	12.	13.	14.	14.	15.	16.	17.	19.	20.	22.	24.
290	13.	14.	14.	15.	16.	17.	19.	20.	22.	23.	26.
300	14.	15.	16.	16.	17.	19.	20.	22.	23.	25.	28.
310	15.	16.	17.	17.	19.	20.	21.	23.	25.	27.	29.
320	16.	17.	18.	19.	20.	21.	23.	25.	27.	29.	31.
325 RS	16.	17.	18.	19.	21.	22.	23.	25.	27.	29.	32.
330	17.	18.	19.	20.	21.	23.	24.	26.	28.	30.	33.
340	18.	19.	20.	21.	22.	24.	25.	28.	30.	32.	35.
350	19.	20.	21.	22.	24.	25.	27.	29.	32.	34.	37.
360	20.	21.	22.	23.	25.	27.	29.	31.	34.	36.	40.
370	21.	22.	24.	25.	27.	28.	30.	33.	35.	38.	42.
380	22.	24.	25.	26.	28.	30.	32.	35.	37.	40.	44.
390	23.	25.	26.	28.	30.	32.	34.	36.	39.	42.	47.
400	25.	26.	28.	29.	31.	33.	35.	38.	41.	45.	49.
410	26.	27.	29.	30.	33.	35.	37.	40.	44.	47.	51.
420	27.	29.	30.	32.	34.	37.	39.	42.	46.	49.	54.
430	29.	30.	32.	34.	36.	38.	41.	44.	48.	51.	57.

INITIAL STRINGING SAGS AND TENSIONS

DESIGN POINTS

TEMP,F	ICE,IN.	WIND,PSF	FINAL SAG, FT.	FINAL TENSION, LB.	INITIAL SAG, FT.	INITIAL TENSION, LB.
CREEP IS NOT A FACTOR						
0.0	1/2	4	6.91	2190.	6.91	(2190.)
32.0	1/2		6.10	1526.	5.47	1701.
60.0		4	4.09	635.	2.50	1041.
60.0		6	4.48	727.	2.97	1094.
-20.0			1.64	1171.	1.24	1545.
0.0			1.97	973.	1.36	1411.
30.0			2.68	717.	1.60	1203.
60.0			3.61	532.	1.94	989.
90.0			4.37	439.	2.45	783.
120.0			4.78	402.	3.17	605.
140.0			5.07	379.	3.75	512.
167.0			5.46	352.	4.59	418.
200.0			5.94	324.	5.61	343.
212.0			6.11	314.	5.80	331.

RULING SPAN SAGS AND TENSIONS

CONDUCTOR 1/0 (6/1) ACSR **DESIGN RULING SPAN** 375 **FT.** **DESIGN TENSION** 2200 **LBS.**

RECOMMENDED FOR USE WITH RULING SPANS FROM 350 **FT. TO** 425 **FT.** HEAVY **LOADING DISTRICT**

	PHASE	NEUTRAL
CONDUCTOR DESC.	1/0 (6/1) ACSR	1/0 (6/1) ACSR
MAX. OPERATING TEMP.	120. DEGREES F	120.DEGREES F
BASIC GROUND CLEAR.	20.0 FEET	18.0 FEET
DESIGN TENSION	2190. LBS (50.0 %)	2190. LBS (50.0 %)

375. FOOT RULING SPAN HEAVY LOADING DISTRICT

FOR USE WITH A1,B1,AND C1 TYPE ASSEMBLIES

35.0 FOOT POLES QUARTER POINT OF SPAN	35.0 FOOT POLES CENTER OF SPAN	SPAN LENGTH	40.0 FOOT POLES CENTER OF SPAN	40.0 FOOT POLES QUARTER POINT OF SPAN	UPLIFT FACTOR
5.4	5.0	184.	10.0	10.4	1.2
5.1	4.5	203.	9.5	10.1	1.6
4.7	4.0	222.	9.0	9.7	2.1
4.4	3.5	239.	8.5	9.4	2.6
4.1	3.0	255.	8.0	9.1	3.1
3.7	2.5	271.	7.5	8.7	3.7
3.4	2.0	286.	7.0	8.4	4.2
3.1	1.5	301.	6.5	8.1	4.8
2.7	1.0	315.	6.0	7.7	5.3
2.4	0.5	328.	5.5	7.4	5.9
2.0	LEVEL 0.0	342.	5.0	7.0	6.4
1.7	-0.5	354.	4.5	6.7	7.0
1.4	-1.0	367.	4.0	6.4	7.6
1.0	-1.5	379.	3.5	6.0	8.2
0.7	-2.0	391.	3.0	5.7	8.7
0.3	-2.5	403.	2.5	5.3	9.3
0.0	-3.0	414.	2.0	5.0	9.9
-0.4	-3.5	425.	1.5	4.6	10.5
-0.7	-4.0	436.	1.0	4.3	11.1
-1.1	-4.5	447.	0.5	3.9	11.7
-1.4	-5.0	457.	LEVEL 0.0	3.6	12.3
-1.8	-5.5	468.	-0.5	3.2	12.9
-2.1	-6.0	478.	-1.0	2.9	13.6
-2.5	-6.5	488.	-1.5	2.5	14.2
-2.8	-7.0	498.	-2.0	2.2	14.8
-3.2	-7.5	507.	-2.5	1.8	15.4
-3.5	-8.0	517.	-3.0	1.5	16.0
-3.9	-8.5	526.	-3.5	1.1	16.7
-4.2	-9.0	536.	-4.0	0.8	17.3
-4.6	-9.5	545.	-4.5	0.4	17.9
-4.9	-10.0	554.	-5.0	0.1	18.5

ALL DISTANCES ARE IN FEET

TABLE INCLUDES A 1.0 FOOT STAKING AND CONSTRUCTION TOLERANCE IN ADDITION TO THE BASIC CLEARANCES
TABLE INCLUDES A 1.0 FOOT UPLIFT FACTOR TOLERANCE

THIS TABLE MAY BE USED FOR ANY PHASE CONDUCTOR WHOSE MAXIMUM TEMPERATURE IS 120 DEGREES F OR LESS, AND WHOSE 60 DEGREE F FINAL SAG IN A 375. FOOT SPAN IS LESS THAN OR EQUAL TO 5.8 FEET

STAKING TABLE

TEMP F	0	10	20	30	40	50	60	70	80	90	100
HORIZONTAL TENSION	1142	1075	1008	941	878	816	754	702	651	600	562
SPAN FT.	STRINGING SAG-INCHES										
250	12.	13.	14.	14.	16.	17.	18.	20.	21.	23.	24.
260	13.	14.	15.	16.	17.	18.	20.	21.	23.	25.	26.
270	14.	15.	16.	17.	18.	20.	21.	23.	25.	26.	29.
280	15.	16.	17.	18.	20.	21.	23.	25.	27.	28.	31.
290	16.	17.	18.	19.	21.	23.	24.	26.	28.	31.	33.
300	17.	18.	20.	21.	23.	24.	26.	28.	30.	33.	35.
310	18.	20.	21.	22.	24.	26.	28.	30.	33.	35.	38.
320	20.	21.	22.	24.	26.	28.	30.	32.	35.	37.	40.
330	21.	22.	24.	25.	27.	29.	31.	34.	37.	40.	43.
340	22.	24.	25.	27.	29.	31.	33.	36.	39.	42.	45.
350	23.	25.	27.	28.	31.	33.	35.	38.	41.	45.	48.
360	25.	27.	28.	30.	33.	35.	37.	41.	44.	47.	51.
370	26.	28.	30.	32.	34.	37.	40.	43.	46.	50.	54.
375 RS	27.	29.	31.	33.	35.	38.	41.	44.	48.	51.	55.
380	28.	30.	31.	33.	36.	39.	42.	45.	49.	52.	57.
390	29.	31.	33.	35.	38.	41.	44.	48.	52.	55.	60.
400	31.	33.	35.	37.	40.	43.	46.	50.	54.	58.	63.
410	32.	34.	37.	39.	42.	45.	49.	53.	57.	61.	66.
420	34.	36.	38.	41.	44.	48.	51.	55.	60.	64.	69.
430	35.	38.	40.	43.	46.	50.	53.	58.	63.	67.	72.
440	37.	40.	42.	45.	49.	52.	56.	61.	66.	70.	76.
450	39.	41.	44.	47.	51.	55.	59.	64.	69.	74.	79.
460	40.	43.	46.	49.	53.	57.	61.	66.	72.	77.	83.
470	42.	45.	48.	51.	55.	60.	64.	69.	75.	80.	87.
480	44.	47.	50.	53.	58.	62.	67.	72.	78.	84.	90.
490	46.	49.	52.	56.	60.	65.	69.	75.	81.	87.	94.
500	48.	51.	55.	58.	63.	68.	72.	78.	85.	91.	98.

INITIAL STRINGING SAGS AND TENSIONS

DESIGN POINTS TEMP,F	ICE,IN.	WIND,PSF	FINAL SAG, FT.	FINAL TENSION, LB.	INITIAL SAG, FT.	INITIAL TENSION, LB.
CREEP IS NOT A FACTOR						
0.0	1/2	4	9.21	2190.	9.21	(2190.)
32.0	1/2		8.31	1492.	7.54	1645.
60.0		4	6.28	551.	4.11	842.
60.0		6	6.66	652.	4.69	924.
-20.0			3.02	845.	2.00	1277.
0.0			3.65	701.	2.24	1142.
30.0			4.72	541.	2.72	941.
60.0			5.83	438.	3.39	754.
90.0			6.42	399.	4.26	600.
120.0			6.90	371.	5.26	486.
140.0			7.22	355.	5.94	430.
167.0			7.65	335.	6.84	374.
200.0			8.17	313.	7.84	327.
212.0			8.36	306.	8.02	319.

RULING SPAN SAGS AND TENSIONS

CONDUCTOR 1/0 (6/1) ACSR **DESIGN RULING SPAN** 425 **FT.** **DESIGN TENSION** 2200 **LBS.**

RECOMMENDED FOR USE WITH RULING SPANS FROM 400 **FT. TO** 475 **FT.** HEAVY **LOADING DISTRICT**

	PHASE	NEUTRAL
CONDUCTOR DESC.	1/0 (6/1) ACSR	1/0 (6/1) ACSR
MAX. OPERATING TEMP.	120. DEGREES F	120.DEGREES F
BASIC GROUND CLEAR.	20.0 FEET	18.0 FEET
DESIGN TENSION	2190 LBS (50.0 %)	2190 LBS (50.0 %)

425. FOOT RULING SPAN HEAVY LOADING DISTRICT

FOR USE WITH A1,B1,AND C1 TYPE ASSEMBLIES

35.0 FOOT POLES QUARTER POINT OF SPAN	35.0 FOOT POLES CENTER OF SPAN	SPAN LENGTH	40.0 FOOT POLES CENTER OF SPAN	40.0 FOOT POLES QUARTER POINT OF SPAN	UPLIFT FACTOR
5.4	5.0	197.	10.0	10.4	0.9
5.1	4.5	218.	9.5	10.1	1.4
4.8	4.0	238.	9.0	9.8	1.8
4.5	3.5	257.	8.5	9.5	2.3
4.1	3.0	275.	8.0	9.1	2.8
3.8	2.5	292.	7.5	8.8	3.3
3.5	2.0	309.	7.0	8.5	3.8
3.1	1.5	325.	6.5	8.1	4.3
2.8	1.0	341.	6.0	7.8	4.8
2.5	0.5	356.	5.5	7.5	5.3
2.1	LEVEL 0.0	371.	5.0	7.1	5.8
1.8	-0.5	385.	4.5	6.8	6.4
1.4	-1.0	399.	4.0	6.4	6.9
1.1	-1.5	412.	3.5	6.1	7.5
0.8	-2.0	426.	3.0	5.8	8.0
0.4	-2.5	438.	2.5	5.4	8.6
0.1	-3.0	451.	2.0	5.1	9.1
-0.3	-3.5	464.	1.5	4.7	9.7
-0.6	-4.0	476.	1.0	4.4	10.3
-1.0	-4.5	488.	0.5	4.0	10.8
-1.3	-5.0	499.	LEVEL 0.0	3.7	11.4
-1.7	-5.5	511.	-0.5	3.3	12.0
-2.0	-6.0	522.	-1.0	3.0	12.6
-2.4	-6.5	533.	-1.5	2.6	13.2
-2.7	-7.0	544.	-2.0	2.3	13.8
-3.0	-7.5	555.	-2.5	2.0	14.4
-3.4	-8.0	566.	-3.0	1.6	14.9
-3.7	-8.5	576.	-3.5	1.3	15.5
-4.1	-9.0	586.	-4.0	0.9	16.1
-4.4	-9.5	597.	-4.5	0.6	16.7
-4.8	-10.0	607.	-5.0	0.2	17.3

ALL DISTANCES ARE IN FEET

TABLE INCLUDES A 1.0 FOOT STAKING AND CONSTRUCTION TOLERANCE IN ADDITION TO THE BASIC CLEARANCES
TABLE INCLUDES A 1.0 FOOT UPLIFT FACTOR TOLERANCE

THIS TABLE MAY BE USED FOR ANY PHASE CONDUCTOR WHOSE MAXIMUM TEMPERATURE IS 120 DEGREES F OR LESS, AND WHOSE 60 DEGREE F FINAL SAG IN A 425. FOOT SPAN IS LESS THAN OR EQUAL TO 6.0 FEET

STAKING TABLE

TEMP F	0	10	20	30	40	50	60	70	80	90	100
HORIZONTAL TENSION	1460	1393	1326	1260	1193	1126	1059	995	931	868	812
SPAN FT.	STRINGING SAG-INCHES										
350	18.	19.	20.	21.	23.	24.	25.	27.	29.	31.	33.
360	19.	20.	21.	22.	24.	25.	27.	29.	31.	33.	35.
370	20.	22.	23.	24.	25.	27.	28.	30.	32.	34.	37.
380	22.	23.	24.	25.	27.	28.	30.	32.	34.	36.	39.
390	23.	24.	25.	26.	28.	30.	31.	34.	36.	38.	41.
400	24.	25.	26.	28.	29.	31.	33.	35.	38.	40.	43.
410	25.	26.	28.	29.	31.	33.	35.	37.	40.	42.	46.
420	26.	28.	29.	31.	32.	34.	36.	39.	42.	44.	48.
425 RS	27.	28.	30.	31.	33.	35.	37.	40.	43.	45.	49.
430	28.	29.	31.	32.	34.	36.	38.	41.	44.	46.	50.
440	29.	30.	32.	33.	36.	38.	40.	43.	46.	49.	52.
450	30.	32.	33.	35.	37.	39.	42.	45.	48.	51.	55.
460	32.	33.	35.	37.	39.	41.	44.	47.	50.	53.	57.
470	33.	35.	36.	38.	41.	43.	45.	49.	52.	55.	60.
480	34.	36.	38.	40.	42.	45.	47.	51.	54.	58.	62.
490	36.	38.	40.	42.	44.	47.	49.	53.	57.	60.	65.
500	37.	39.	41.	43.	46.	49.	51.	55.	59.	63.	68.
510	39.	41.	43.	45.	48.	51.	54.	57.	61.	65.	70.
520	40.	43.	45.	47.	50.	53.	56.	60.	64.	68.	73.

INITIAL STRINGING SAGS AND TENSIONS

DESIGN POINTS

TEMP,F	ICE,IN.	WIND,PSF	FINAL SAG, FT.	FINAL TENSION, LB.	INITIAL SAG, FT.	INITIAL TENSION, LB.
CREEP IS NOT A FACTOR						
0.0	1/2	4	11.84	2190.	11.84	(2190.)
32.0	1/2		10.84	1466.	9.98	1596.
60.0		4	8.88	502.	6.42	693.
60.0		6	9.23	604.	7.01	795.
-20.0			5.35	614.	3.32	987.
0.0			6.16	533.	3.79	866.
30.0			7.35	447.	4.66	705.
60.0			8.37	393.	5.68	578.
90.0			8.89	370.	6.78	485.
120.0			9.41	350.	7.86	418.
140.0			9.75	337.	8.56	384.
167.0			10.21	322.	9.46	348.
200.0			10.76	306.	10.40	316.
212.0			10.95	301.	10.60	311.

RULING SPAN SAGS AND TENSIONS

CONDUCTOR 4/0 (6/1) ACSR **DESIGN RULING SPAN** 300 **FT. DESIGN TENSION** 3675 **LBS.**

RECOMMENDED FOR USE WITH RULING SPANS FROM 275 **FT. TO** 375 **FT.** HEAVY **LOADING DISTRICT**

	PHASE	NEUTRAL
CONDUCTOR DESC.	4/0 (6/1) ACSR	4/0 (6/1) ACSR
MAX. OPERATING TEMP.	120. DEGREES F	120.DEGREES F
BASIC GROUND CLEAR.	20.0 FEET	18.0 FEET
DESIGN TENSION	3346. LBS (40.1 %)	3346. LBS (40.1 %)

300. FOOT RULING SPAN HEAVY LOADING DISTRICT

FOR USE WITH A1,B1,AND C1 TYPE ASSEMBLIES

35.0 FOOT POLES QUARTER POINT OF SPAN	35.0 FOOT POLES CENTER OF SPAN	SPAN LENGTH	40.0 FOOT POLES CENTER OF SPAN	40.0 FOOT POLES QUARTER POINT OF SPAN	UPLIFT FACTOR
5.4	5.0	197.	10.0	10.4	1.3
5.1	4.5	218.	9.5	10.1	1.8
4.8	4.0	238.	9.0	9.8	2.3
4.5	3.5	257.	8.5	9.5	2.9
4.1	3.0	275.	8.0	9.1	3.5
3.8	2.5	293.	7.5	8.8	4.0
3.5	2.0	310.	7.0	8.5	4.6
3.1	1.5	326.	6.5	8.1	5.2
2.8	1.0	341.	6.0	7.8	5.8
2.5	0.5	357.	5.5	7.5	6.5
2.1	LEVEL 0.0	371.	5.0	7.1	7.1
1.8	-0.5	386.	4.5	6.8	7.7
1.4	-1.0	400.	4.0	6.4	8.4
1.1	-1.5	413.	3.5	6.1	9.0
0.8	-2.0	427.	3.0	5.8	9.7
0.4	-2.5	440.	2.5	5.4	10.3
0.1	-3.0	452.	2.0	5.1	11.0
-0.3	-3.5	465.	1.5	4.7	11.7
-0.6	-4.0	477.	1.0	4.4	12.3
-1.0	-4.5	489.	0.5	4.0	13.0
-1.3	-5.0	501.	LEVEL 0.0	3.7	13.7
-1.7	-5.5	512.	-0.5	3.3	14.4
-2.0	-6.0	524.	-1.0	3.0	15.1
-2.4	-6.5	535.	-1.5	2.6	15.8
-2.7	-7.0	546.	-2.0	2.3	16.5
-3.0	-7.5	556.	-2.5	2.0	17.2
-3.4	-8.0	567.	-3.0	1.6	17.9
-3.7	-8.5	578.	-3.5	1.3	18.6
-4.1	-9.0	588.	-4.0	0.9	19.3
-4.4	-9.5	598.	-4.5	0.6	20.0
-4.8	-10.0	608.	-5.0	0.2	20.7

ALL DISTANCES ARE IN FEET

TABLE INCLUDES A 1.0 FOOT STAKING AND CONSTRUCTION TOLERANCE IN ADDITION TO THE BASIC CLEARANCES
TABLE INCLUDES A 1.0 FOOT UPLIFT FACTOR TOLERANCE

THIS TABLE MAY BE USED FOR ANY PHASE CONDUCTOR WHOSE MAXIMUM TEMPERATURE IS 120 DEGREES F OR LESS, AND WHOSE 60 DEGREE F FINAL SAG IN A 300. FOOT SPAN IS LESS THAN OR EQUAL TO 3.0 FEET

STAKING TABLE

TEMP F	0	10	20	30	40	50	60	70	80	90	100
HORIZONTAL TENSION	2477	2334	2191	2049	1908	1767	1626	1499	1372	1245	1148
SPAN FT.	STRINGING SAG-INCHES										
200	7.	8.	8.	9.	9.	10.	11.	12.	13.	14.	15.
210	8.	8.	9.	9.	10.	11.	12.	13.	14.	15.	17.
220	9.	9.	10.	10.	11.	12.	13.	14.	16.	17.	19.
230	9.	10.	11.	11.	12.	13.	14.	16.	17.	19.	20.
240	10.	11.	12.	12.	13.	14.	15.	17.	19.	20.	22.
250	11.	12.	13.	13.	14.	16.	17.	19.	20.	22.	24.
260	12.	13.	14.	14.	16.	17.	18.	20.	22.	24.	26.
270	13.	14.	15.	16.	17.	18.	20.	22.	24.	26.	28.
280	14.	15.	16.	17.	18.	20.	21.	23.	25.	28.	30.
290	15.	16.	17.	18.	19.	21.	23.	25.	27.	30.	33.
300 RS	16.	17.	18.	19.	21.	23.	24.	27.	29.	32.	35.
310	17.	18.	19.	20.	22.	24.	26.	28.	31.	34.	37.
320	18.	19.	21.	22.	24.	26.	28.	30.	33.	36.	40.
330	19.	21.	22.	23.	25.	27.	29.	32.	35.	38.	42.
340	20.	22.	23.	25.	27.	29.	31.	34.	37.	41.	45.
350	22.	23.	25.	26.	28.	31.	33.	36.	40.	43.	47.
360	23.	24.	26.	28.	30.	32.	35.	38.	42.	45.	50.
370	24.	26.	27.	29.	32.	34.	37.	41.	44.	48.	53.
380	25.	27.	29.	31.	33.	36.	39.	43.	47.	51.	56.
390	27.	29.	31.	32.	35.	38.	41.	45.	49.	53.	59.
400	28.	30.	32.	34.	37.	40.	43.	47.	52.	56.	62.
410	30.	32.	34.	36.	39.	42.	45.	50.	54.	59.	65.
420	31.	33.	35.	38.	41.	44.	47.	52.	57.	62.	68.
430	33.	35.	37.	39.	43.	46.	50.	55.	60.	65.	71.
440	34.	37.	39.	41.	45.	48.	52.	57.	63.	68.	75.
450	36.	38.	41.	43.	47.	51.	54.	60.	66.	71.	78.

INITIAL STRINGING SAGS AND TENSIONS

DESIGN POINTS

CREEP IS NOT A FACTOR

TEMP,F	ICE,IN.	WIND,PSF	FINAL SAG, FT.	FINAL TENSION, LB.	INITIAL SAG, FT.	INITIAL TENSION, LB.
0.0	1/2	4	4.66	3346.	4.66	3346.
32.0	1/2		4.39	2443.	4.03	2658.
60.0		4	3.22	1212.	2.31	1689.
60.0		6	3.46	1318.	2.59	1759.
-20.0			1.31	2503.	1.19	2754.
0.0			1.57	(2088.)	1.32	2477.
30.0			2.14	1531.	1.60	2049.
60.0			2.96	1108.	2.01	1626.
90.0			3.91	839.	2.63	1245.
120.0			4.58	715.	3.44	954.
140.0			4.86	675.	4.03	814.
167.0			5.23	627.	4.82	681.
200.0			5.69	577.	5.55	591.
212.0			5.85	561.	5.72	574.

RULING SPAN SAGS AND TENSIONS

CONDUCTOR 4/0 (6/1) ACSR **DESIGN RULING SPAN** 375 **FT.** **DESIGN TENSION** 4000 **LBS.**

RECOMMENDED FOR USE WITH RULING SPANS FROM 350 **FT. TO** 425 **FT.** HEAVY **LOADING DISTRICT**

	PHASE	NEUTRAL
CONDUCTOR DESC.	4/0 (6/1) ACSR	4/0 (6/1) ACSR
MAX. OPERATING TEMP.	120. DEGREES F	120.DEGREES F
BASIC GROUND CLEAR.	20.0 FEET	18.0 FEET
DESIGN TENSION	3675. LBS (44.0 %)	3675. LBS (44.0 %)

375. FOOT RULING SPAN HEAVY LOADING DISTRICT

FOR USE WITH A1,B1,AND C1 TYPE ASSEMBLIES

35.0 FOOT QUARTER POINT OF SPAN	POLES CENTER OF SPAN	SPAN LENGTH	40.0 FOOT CENTER OF SPAN	POLES QUARTER POINT OF SPAN	UPLIFT FACTOR
5.4	5.0	202.	10.0	10.4	1.3
5.1	4.5	224.	9.5	10.1	1.8
4.8	4.0	244.	9.0	9.8	2.4
4.5	3.5	264.	8.5	9.5	2.9
4.1	3.0	283.	8.0	9.1	3.5
3.2	2.5	301.	7.5	8.2	4.1
2.8	2.0	319.	7.0	7.8	4.7
2.4	1.5	336.	6.5	7.4	5.4
1.9	1.0	353.	6.0	6.9	6.0
1.5	0.5	369.	5.5	6.5	6.7
1.1	LEVEL 0.0	384.	5.0	6.1	7.3
0.7	-0.5	398.	4.5	5.7	7.9
0.3	-1.0	412.	4.0	5.3	8.6
1.1	-1.5	426.	3.5	6.1	9.2
0.8	-2.0	440.	3.0	5.8	9.9
0.4	-2.5	453.	2.5	5.4	10.6
0.1	-3.0	466.	2.0	5.1	11.2
-0.2	-3.5	479.	1.5	4.8	11.9
-0.6	-4.0	492.	1.0	4.4	12.6
-0.9	-4.5	504.	0.5	4.1	13.3
-1.3	-5.0	517.	LEVEL 0.0	3.7	14.0
-1.6	-5.5	529.	-0.5	3.4	14.7
-2.0	-6.0	540.	-1.0	3.0	15.4
-2.3	-6.5	552.	-1.5	2.7	16.2
-2.7	-7.0	563.	-2.0	2.3	16.9
-3.0	-7.5	575.	-2.5	2.0	17.6
-3.3	-8.0	586.	-3.0	1.7	18.3
-3.7	-8.5	597.	-3.5	1.3	19.0
-4.0	-9.0	607.	-4.0	1.0	19.8
-4.4	-9.5	618.	-4.5	0.6	20.5
-4.7	-10.0	628.	-5.0	0.3	21.2

ALL DISTANCES ARE IN FEET

TABLE INCLUDES A 1.0 FOOT STAKING AND CONSTRUCTION TOLERANCE IN ADDITION TO THE BASIC CLEARANCES
TABLE INCLUDES A 1.0 FOOT UPLIFT FACTOR TOLERANCE

THIS TABLE MAY BE USED FOR ANY PHASE CONDUCTOR WHOSE MAXIMUM TEMPERATURE IS 120 DEGREES F OR LESS, AND WHOSE 60 DEGREE F FINAL SAG IN A 375. FOOT SPAN IS LESS THAN OR EQUAL TO 4.3 FEET

STAKING TABLE

TEMP F	0	10	20	30	40	50	60	70	80	90	100
HORIZONTAL TENSION	2587	2450	2313	2177	2042	1908	1774	1653	1532	1411	1316
SPAN FT.	STRINGING SAG-INCHES										
250	11.	11.	12.	13.	13.	14.	15.	17.	18.	19.	21.
260	11.	12.	13.	14.	15.	16.	17.	18.	19.	21.	23.
270	12.	13.	14.	15.	16.	17.	18.	19.	21.	23.	24.
280	13.	14.	15.	16.	17.	18.	19.	21.	23.	24.	26.
290	14.	15.	16.	17.	18.	19.	21.	22.	24.	26.	28.
300	15.	16.	17.	18.	19.	21.	22.	24.	26.	28.	30.
310	16.	17.	18.	19.	21.	22.	24.	26.	28.	30.	32.
320	17.	18.	19.	21.	22.	24.	25.	27.	30.	32.	34.
330	18.	20.	21.	22.	24.	25.	27.	29.	31.	34.	37.
340	20.	21.	22.	23.	25.	27.	28.	31.	33.	36.	39.
350	21.	22.	23.	25.	26.	28.	30.	33.	35.	38.	41.
360	22.	23.	25.	26.	28.	30.	32.	35.	37.	40.	44.
370	23.	25.	26.	27.	30.	32.	34.	37.	39.	42.	46.
375 RS	24.	25.	27.	28.	30.	32.	35.	38.	41.	44.	47.
380	24.	26.	27.	29.	31.	33.	36.	39.	42.	45.	48.
390	26.	27.	29.	31.	33.	35.	37.	41.	44.	47.	51.
400	27.	29.	30.	32.	35.	37.	39.	43.	46.	50.	54.
410	28.	30.	32.	34.	36.	39.	41.	45.	48.	52.	56.
420	30.	32.	34.	35.	38.	41.	43.	47.	51.	55.	59.
430	31.	33.	35.	37.	40.	43.	46.	49.	53.	57.	62.
440	33.	35.	37.	39.	42.	45.	48.	52.	56.	60.	65.
450	34.	36.	38.	41.	44.	47.	50.	54.	58.	63.	68.
460	36.	38.	40.	42.	46.	49.	52.	57.	61.	65.	71.
470	37.	40.	42.	44.	48.	51.	54.	59.	64.	68.	74.
480	39.	41.	44.	46.	50.	53.	57.	62.	66.	71.	77.
490	41.	43.	46.	48.	52.	55.	59.	64.	69.	74.	81.
500	42.	45.	48.	50.	54.	58.	62.	67.	72.	77.	84.

INITIAL STRINGING SAGS AND TENSIONS

DESIGN POINTS TEMP,F	ICE,IN.	WIND,PSF	FINAL SAG, FT.	FINAL TENSION, LB.	INITIAL SAG, FT.	INITIAL TENSION, LB.
CREEP IS NOT A FACTOR						
0.0	1/2	4	6.64	3675.	6.64	3675.
32.0	1/2		6.21	2702.	5.71	2937.
60.0		4	4.59	1327.	3.29	1853.
60.0		6	4.91	1452.	3.67	1938.
-20.0			2.06	2479.	1.79	2856.
0.0			2.45	(2088.)	1.98	2587.
30.0			3.24	1580.	2.35	2177.
60.0			4.26	1203.	2.88	1774.
90.0			5.37	954.	3.62	1412.
120.0			6.21	825.	4.55	1125.
140.0			6.53	785.	5.23	980.
167.0			6.97	736.	6.15	833.
200.0			7.49	684.	7.24	708.
212.0			7.69	667.	7.50	684.

RULING SPAN SAGS AND TENSIONS

CONDUCTOR 4/0 (6/1) ACSR DESIGN RULING SPAN 425 FT. DESIGN TENSION 4000 LBS.

RECOMMENDED FOR USE WITH RULING SPANS FROM 400 FT. TO 475 FT. HEAVY LOADING DISTRICT

	PHASE	NEUTRAL
CONDUCTOR DESC.	4/0 (6/1) ACSR	4/0 (6/1) ACSR
MAX. OPERATING TEMP.	120. DEGREES F	120.DEGREES F
BASIC GROUND CLEAR.	20.0 FEET	18.0 FEET
DESIGN TENSION	3882 LBS (46.5 %)	3882 LBS (46.5 %)

425. FOOT RULING SPAN HEAVY LOADING DISTRICT

FOR USE WITH A1,B1,AND C1 TYPE ASSEMBLIES

35.0 FOOT POLES QUARTER POINT OF SPAN	35.0 FOOT POLES CENTER OF SPAN	SPAN LENGTH	40.0 FOOT POLES CENTER OF SPAN	40.0 FOOT POLES QUARTER POINT OF SPAN	UPLIFT FACTOR
5.4	5.0	204.	10.0	10.4	1.3
5.1	4.5	227.	9.5	10.1	1.8
4.8	4.0	248.	9.0	9.8	2.4
4.0	3.5	268.	8.5	9.0	2.9
3.6	3.0	290.	8.0	8.6	3.6
3.2	2.5	310.	7.5	8.2	4.3
2.8	2.0	329.	7.0	7.8	4.9
2.4	1.5	347.	6.5	7.4	5.6
2.0	1.0	363.	6.0	7.0	6.2
1.6	0.5	380.	5.5	6.6	6.9
1.1	LEVEL 0.0	395.	5.0	6.1	7.5
0.7	-0.5	410.	4.5	5.7	8.2
0.3	-1.0	424.	4.0	5.3	8.9
-0.1	-1.5	438.	3.5	4.9	9.5
-0.5	-2.0	452.	3.0	4.5	10.2
-0.9	-2.5	465.	2.5	4.1	10.8
-1.3	-3.0	478.	2.0	3.7	11.5
-1.8	-3.5	490.	1.5	3.2	12.1
-2.2	-4.0	502.	1.0	2.8	12.8
-2.6	-4.5	514.	0.5	2.4	13.5
-1.2	-5.0	526.	LEVEL 0.0	3.8	14.1
-1.6	-5.5	538.	-0.5	3.4	14.8
-1.9	-6.0	550.	-1.0	3.1	15.6
-2.3	-6.5	562.	-1.5	2.7	16.3
-2.6	-7.0	574.	-2.0	2.4	17.0
-3.0	-7.5	585.	-2.5	2.0	17.7
-3.3	-8.0	597.	-3.0	1.7	18.5
-3.7	-8.5	608.	-3.5	1.3	19.2
-4.0	-9.0	619.	-4.0	1.0	19.9
-4.4	-9.5	630.	-4.5	0.6	20.7
-4.7	-10.0	640.	-5.0	0.3	21.4

ALL DISTANCES ARE IN FEET

TABLE INCLUDES A 1.0 FOOT STAKING AND CONSTRUCTION TOLERANCE IN ADDITION TO THE BASIC CLEARANCES
TABLE INCLUDES A 1.0 FOOT UPLIFT FACTOR TOLERANCE

THIS TABLE MAY BE USED FOR ANY PHASE CONDUCTOR WHOSE MAXIMUM TEMPERATURE IS 120 DEGREES F OR LESS, AND WHOSE 60 DEGREE F FINAL SAG IN A 425. FOOT SPAN IS LESS THAN OR EQUAL TO 5.2 FEET

STAKING TABLE

TEMP F	0	10	20	30	40	50	60	70	80	90	100
HORIZONTAL TENSION	2656	2524	2391	2258	2127	1997	1866	1749	1632	1515	1420
SPAN FT.	STRINGING SAG-INCHES										
350	20.	21.	23.	24.	25.	27.	29.	31.	33.	35.	38.
360	21.	23.	24.	25.	27.	29.	30.	33.	35.	37.	40.
370	22.	24.	25.	26.	28.	30.	32.	35.	37.	39.	43.
380	24.	25.	27.	28.	30.	32.	34.	36.	39.	42.	45.
390	25.	26.	28.	29.	31.	34.	36.	38.	41.	44.	47.
400	26.	28.	29.	31.	33.	35.	37.	40.	43.	46.	50.
410	28.	29.	31.	33.	35.	37.	39.	42.	45.	48.	52.
420	29.	31.	32.	34.	37.	39.	41.	44.	48.	51.	55.
425 RS	30.	31.	33.	35.	37.	40.	42.	46.	49.	52.	56.
430	30.	32.	34.	36.	38.	41.	43.	47.	50.	53.	57.
440	32.	34.	36.	37.	40.	43.	45.	49.	52.	56.	60.
450	33.	35.	37.	39.	42.	45.	47.	51.	55.	58.	63.
460	35.	37.	39.	41.	44.	47.	50.	53.	57.	61.	66.
470	36.	38.	41.	43.	46.	49.	52.	56.	60.	64.	69.
480	38.	40.	42.	45.	48.	51.	54.	58.	62.	66.	72.
490	39.	42.	44.	46.	50.	53.	56.	61.	65.	69.	75.
500	41.	44.	46.	48.	52.	55.	58.	63.	68.	72.	78.
510	43.	45.	48.	50.	54.	57.	61.	66.	70.	75.	81.
520	44.	47.	50.	52.	56.	60.	63.	68.	73.	78.	84.

INITIAL STRINGING SAGS AND TENSIONS

DESIGN POINTS TEMP,F	ICE,IN.	WIND,PSF	FINAL SAG, FT.	FINAL TENSION, LB.	INITIAL SAG, FT.	INITIAL TENSION, LB.
CREEP IS NOT A FACTOR						
0.0	1/2	4	8.07	3882.	8.07	3882.
32.0	1/2		7.52	2863.	6.92	3113.
60.0		4	5.61	1396.	4.00	1956.
60.0		6	5.97	1533.	4.46	2051.
-20.0			2.67	2461.	2.25	2921.
0.0			3.15	(2088.)	2.47	2658.
30.0			4.08	1612.	2.91	2258.
60.0			5.22	1260.	3.52	1867.
90.0			6.43	1023.	4.34	1516.
120.0			7.38	892.	5.34	1231.
140.0			7.72	852.	6.07	1084.
167.0			8.19	804.	7.07	930.
200.0			8.77	751.	8.27	797.
212.0			8.98	734.	8.68	759.

RULING SPAN SAGS AND TENSIONS

CONDUCTOR NO. 4 (7/1) ACSR **DESIGN RULING SPAN** 325 **FT. DESIGN TENSION** 1250 **LBS.**

RECOMMENDED FOR USE WITH RULING SPANS FROM 300 **FT. TO** 425 **FT.** MEDIUM **LOADING DISTRICT**

	PHASE	NEUTRAL
CONDUCTOR DESC.	NO. 4(7/1) ACSR	NO. 4(7/1) ACSR
MAX. OPERATING TEMP.	120. DEGREES F	120.DEGREES F
BASIC GROUND CLEAR.	20.0 FEET	18.0 FEET
DESIGN TENSION	1104. LBS (46.8 %)	1104. LBS (46.8 %)

325. FOOT RULING SPAN MEDIUM LOADING DISTRICT

FOR USE WITH A1,B1,AND C1 TYPE ASSEMBLIES

35.0 FOOT QUARTER POINT OF SPAN	POLES CENTER OF SPAN	SPAN LENGTH	40.0 FOOT CENTER OF SPAN	POLES QUARTER POINT OF SPAN	UPLIFT FACTOR
5.4	5.0	259.	10.0	10.4	1.9
5.1	4.5	282.	9.5	10.1	2.5
4.8	4.0	304.	9.0	9.8	3.1
4.4	3.5	326.	8.5	9.4	3.7
4.1	3.0	347.	8.0	9.1	4.3
3.8	2.5	366.	7.5	8.8	4.9
3.5	2.0	386.	7.0	8.5	5.5
3.1	1.5	405.	6.5	8.1	6.2
2.8	1.0	423.	6.0	7.8	6.9
2.5	0.5	440.	5.5	7.5	7.5
2.1	LEVEL 0.0	458.	5.0	7.1	8.2
1.8	-0.5	475.	4.5	6.8	8.9
1.5	-1.0	491.	4.0	6.5	9.6
1.1	-1.5	507.	3.5	6.1	10.3
0.8	-2.0	523.	3.0	5.8	11.0
0.5	-2.5	538.	2.5	5.5	11.7
0.1	-3.0	553.	2.0	5.1	12.5
-0.2	-3.5	568.	1.5	4.8	13.2
-0.5	-4.0	583.	1.0	4.5	13.9
-0.9	-4.5	597.	0.5	4.1	14.7
-1.2	-5.0	611.	LEVEL 0.0	3.8	15.4
-1.6	-5.5	625.	-0.5	3.4	16.2
-1.9	-6.0	639.	-1.0	3.1	16.9
-2.2	-6.5	652.	-1.5	2.8	17.7
-2.6	-7.0	665.	-2.0	2.4	18.4
-2.9	-7.5	678.	-2.5	2.1	19.2
-3.3	-8.0	691.	-3.0	1.7	20.0
-3.6	-8.5	704.	-3.5	1.4	20.8
-4.0	-9.0	716.	-4.0	1.0	21.5
-4.3	-9.5	729.	-4.5	0.7	22.3
-4.6	-10.0	741.	-5.0	0.4	23.1

ALL DISTANCES ARE IN FEET

TABLE INCLUDES A 1.0 FOOT STAKING AND CONSTRUCTION TOLERANCE IN ADDITION TO THE BASIC CLEARANCES
TABLE INCLUDES A 1.0 FOOT UPLIFT FACTOR TOLERANCE

THIS TABLE MAY BE USED FOR ANY PHASE CONDUCTOR WHOSE MAXIMUM TEMPERATURE IS 120 DEGREES F OR LESS, AND WHOSE 60 DEGREE F FINAL SAG IN A 325. FOOT SPAN IS LESS THAN OR EQUAL TO 2.2 FEET

STAKING TABLE

TEMP F	0	10	20	30	40	50	60	70	80	90	100
HORIZONTAL TENSION	809	776	744	711	675	640	604	567	529	492	455
SPAN FT.	STRINGING SAG-INCHES										
200	5.	5.	5.	6.	6.	6.	7.	7.	8.	8.	9.
210	5.	6.	6.	6.	7.	7.	7.	8.	8.	9.	10.
220	6.	6.	7.	7.	7.	8.	8.	9.	9.	10.	11.
230	7.	7.	7.	7.	8.	8.	9.	9.	10.	11.	12.
240	7.	7.	8.	8.	9.	9.	10.	10.	11.	12.	13.
250	8.	8.	8.	9.	9.	10.	10.	11.	12.	13.	14.
260	8.	9.	9.	10.	10.	11.	11.	12.	13.	14.	15.
270	9.	9.	10.	10.	11.	12.	12.	13.	14.	15.	16.
280	10.	10.	11.	11.	12.	12.	13.	14.	15.	16.	18.
290	10.	11.	11.	12.	13.	13.	14.	15.	16.	17.	19.
300	11.	12.	12.	13.	13.	14.	15.	16.	17.	18.	20.
310	12.	12.	13.	14.	14.	15.	16.	17.	18.	20.	22.
320	13.	13.	14.	14.	15.	16.	17.	18.	20.	21.	23.
325 RS	13.	14.	14.	15.	16.	17.	18.	19.	20.	22.	24.
330	14.	14.	15.	15.	16.	17.	18.	19.	21.	22.	24.
340	14.	15.	16.	16.	17.	18.	19.	21.	22.	24.	26.
350	15.	16.	17.	17.	18.	19.	20.	22.	23.	25.	27.
360	16.	17.	18.	18.	19.	20.	22.	23.	25.	26.	29.
370	17.	18.	19.	19.	20.	22.	23.	25.	26.	28.	31.
380	18.	19.	20.	20.	22.	23.	24.	26.	28.	30.	32.
390	19.	20.	21.	22.	23.	24.	25.	27.	29.	31.	34.
400	20.	21.	22.	23.	24.	25.	27.	29.	31.	33.	36.
410	21.	22.	23.	24.	25.	27.	28.	30.	32.	34.	38.
420	22.	23.	24.	25.	26.	28.	29.	32.	34.	36.	40.
430	23.	24.	25.	26.	28.	29.	31.	33.	35.	38.	41.

INITIAL STRINGING SAGS AND TENSIONS

DESIGN POINTS TEMP,F	ICE,IN.	WIND,PSF	FINAL SAG, FT.	FINAL TENSION, LB.	INITIAL SAG, FT.	INITIAL TENSION, LB.
CREEP IS NOT A FACTOR						
15.0	1/4	4	6.44	1104.	6.44	1104.
32.0	1/4		4.21	706.	3.64	816.
60.0		4	3.13	460.	2.26	636.
60.0		6	3.73	514.	2.87	668.
-20.0			1.17	757.	1.02	870.
0.0			1.34	660.	1.09	809.
15.0			1.50	(590.)	1.16	761.
30.0			1.70	522.	1.24	711.
60.0			2.23	397.	1.46	604.
90.0			2.99	296.	1.80	492.
120.0			3.73	237.	2.33	380.
140.0			4.02	220.	2.82	314.
167.0			4.44	200.	3.63	244.
200.0			4.96	178.	4.59	193.
212.0			5.16	172.	4.78	185.

RULING SPAN SAGS AND TENSIONS

CONDUCTOR NO. 4 (7/1) ACSR **DESIGN RULING SPAN** 425 **FT. DESIGN TENSION** 1350 **LBS.**

RECOMMENDED FOR USE WITH RULING SPANS FROM 400 **FT. TO** 525 **FT.** MEDIUM **LOADING DISTRICT**

	PHASE	NEUTRAL
CONDUCTOR DESC.	NO. 4(7/1) ACSR	NO. 4(7/1) ACSR
MAX. OPERATING TEMP.	120. DEGREES F	120. DEGREES F
BASIC GROUND CLEAR.	20.0 FEET	18.0 FEET
DESIGN TENSION	1233. LBS (52.2 %)	1233. LBS (52.2 %)

425. FOOT RULING SPAN MEDIUM LOADING DISTRICT

FOR USE WITH A1,B1,AND C1 TYPE ASSEMBLIES

35.0 FOOT POLES QUARTER POINT OF SPAN	35.0 FOOT POLES CENTER OF SPAN	SPAN LENGTH	40.0 FOOT POLES CENTER OF SPAN	40.0 FOOT POLES QUARTER POINT OF SPAN	UPLIFT FACTOR
5.4	5.0	255.	10.0	10.4	1.8
5.1	4.5	278.	9.5	10.1	2.3
4.8	4.0	300.	9.0	9.8	2.8
4.4	3.5	321.	8.5	9.4	3.4
4.1	3.0	342.	8.0	9.1	4.0
3.8	2.5	361.	7.5	8.8	4.5
3.5	2.0	380.	7.0	8.5	5.1
3.1	1.5	398.	6.5	8.1	5.8
2.8	1.0	416.	6.0	7.8	6.4
2.5	0.5	434.	5.5	7.5	7.0
2.1	LEVEL 0.0	451.	5.0	7.1	7.6
1.8	-0.5	467.	4.5	6.8	8.3
1.5	-1.0	483.	4.0	6.5	8.9
1.1	-1.5	499.	3.5	6.1	9.6
0.8	-2.0	514.	3.0	5.8	10.2
0.4	-2.5	529.	2.5	5.4	10.9
0.1	-3.0	544.	2.0	5.1	11.6
-0.2	-3.5	559.	1.5	4.8	12.3
-0.6	-4.0	573.	1.0	4.4	13.0
-0.9	-4.5	587.	0.5	4.1	13.6
-1.2	-5.0	601.	LEVEL 0.0	3.8	14.3
-1.6	-5.5	614.	-0.5	3.4	15.0
-1.9	-6.0	628.	-1.0	3.1	15.7
-2.3	-6.5	641.	-1.5	2.7	16.5
-2.6	-7.0	654.	-2.0	2.4	17.2
-3.0	-7.5	666.	-2.5	2.0	17.9
-3.3	-8.0	679.	-3.0	1.7	18.6
-3.6	-8.5	691.	-3.5	1.4	19.3
-4.0	-9.0	704.	-4.0	1.0	20.1
-4.3	-9.5	716.	-4.5	0.7	20.8
-4.7	-10.0	728.	-5.0	0.3	21.5

ALL DISTANCES ARE IN FEET

TABLE INCLUDES A 1.0 FOOT STAKING AND CONSTRUCTION TOLERANCE IN ADDITION TO THE BASIC CLEARANCES

TABLE INCLUDES A 1.0 FOOT UPLIFT FACTOR TOLERANCE

THIS TABLE MAY BE USED FOR ANY PHASE CONDUCTOR WHOSE MAXIMUM TEMPERATURE IS 120 DEGREES F OR LESS, AND WHOSE 60 DEGREE F FINAL SAG IN A 425. FOOT SPAN IS LESS THAN OR EQUAL TO 4.0 FEET

STAKING TABLE

TEMP F	0	10	20	30	40	50	60	70	80	90	100
HORIZONTAL TENSION	834	802	771	739	705	671	637	602	566	531	496
SPAN FT.	STRINGING SAG-INCHES										
320	12.	13.	13.	14.	15.	15.	16.	17.	18.	19.	21.
330	13.	14.	14.	15.	16.	16.	17.	18.	19.	21.	22.
340	14.	15.	15.	16.	17.	17.	18.	19.	21.	22.	24.
350	15.	15.	16.	17.	18.	18.	19.	21.	22.	23.	25.
360	16.	16.	17.	18.	19.	20.	20.	22.	23.	25.	27.
370	16.	17.	18.	19.	20.	21.	22.	23.	24.	26.	28.
380	17.	18.	19.	20.	21.	22.	23.	24.	26.	27.	30.
390	18.	19.	20.	21.	22.	23.	24.	26.	27.	29.	31.
400	19.	20.	21.	22.	23.	24.	25.	27.	29.	30.	33.
410	20.	21.	22.	23.	24.	25.	27.	28.	30.	32.	34.
420	21.	22.	23.	24.	25.	27.	28.	30.	32.	33.	36.
425 RS	22.	23.	24.	25.	26.	27.	29.	30.	32.	34.	37.
430	22.	23.	24.	25.	26.	28.	29.	31.	33.	35.	38.
440	23.	24.	25.	26.	28.	29.	31.	33.	35.	37.	40.
450	24.	25.	26.	28.	29.	30.	32.	34.	36.	38.	41.
460	26.	27.	28.	29.	30.	32.	33.	36.	38.	40.	43.
470	27.	28.	29.	30.	32.	33.	35.	37.	39.	42.	45.
480	28.	29.	30.	31.	33.	35.	36.	39.	41.	44.	47.
490	29.	30.	31.	33.	34.	36.	38.	40.	43.	45.	49.
500	30.	31.	33.	34.	36.	38.	39.	42.	45.	47.	51.
510	31.	33.	34.	35.	37.	39.	41.	44.	47.	49.	53.
520	33.	34.	35.	37.	39.	41.	43.	46.	48.	51.	55.
530	34.	35.	37.	38.	40.	42.	44.	47.	50.	53.	57.
540	35.	37.	38.	40.	42.	44.	46.	49.	52.	55.	60.
550	36.	38.	40.	41.	43.	46.	48.	51.	54.	57.	62.
560	38.	39.	41.	43.	45.	47.	49.	53.	56.	59.	64.
570	39.	41.	43.	44.	47.	49.	51.	55.	58.	62.	67.
580	41.	42.	44.	46.	48.	51.	53.	57.	60.	64.	69.
590	42.	44.	46.	47.	50.	52.	55.	59.	62.	66.	71.
600	43.	45.	47.	49.	52.	54.	57.	61.	64.	68.	74.

INITIAL STRINGING SAGS AND TENSIONS

DESIGN POINTS

CREEP IS NOT A FACTOR

TEMP,F	ICE,IN.	WIND,PSF	FINAL SAG, FT.	FINAL TENSION, LB.	INITIAL SAG, FT.	INITIAL TENSION, LB.
15.0	1/4	4	9.88	1233.	9.88	1233.
32.0	1/4		6.77	750.	5.72	887.
60.0		4	5.25	468.	3.61	681.
60.0		6	6.07	539.	4.52	725.
-20.0			2.16	700.	1.70	892.
0.0			2.48	609.	1.82	834.
15.0			2.78	545.	1.92	(787.1
30.0			3.13	484.	2.05	739.
60.0			4.00	379.	2.38	637.
90.0			5.05	300.	2.85	531.
120.0			5.71	265.	3.54	427.
140.0			6.07	249.	4.14	365.
167.0			6.58	230.	5.11	296.
200.0			7.21	210.	6.39	237.
212.0			7.44	204.	6.82	222.

RULING SPAN SAGS AND TENSIONS

CONDUCTOR NO. 4 (7/1) ACSR DESIGN RULING SPAN 525 FT. DESIGN TENSION 1350 LBS.

RECOMMENDED FOR USE WITH RULING SPANS FROM 500 FT. TO 625 FT. MEDIUM LOADING DISTRICT

	PHASE	NEUTRAL
CONDUCTOR DESC.	NO. 4(7/1) ACSR	NO. 4(7/1) ACSR
MAX. OPERATING TEMP.	120. DEGREES F	120.DEGREES F
BASIC GROUND CLEAR.	20.0 FEET	18.0 FEET
DESIGN TENSION	1339 LBS (56.7 %)	1339 LBS (56.7 %)

525. FOOT RULING SPAN MEDIUM LOADING DISTRICT

FOR USE WITH A1,B1,AND C1 TYPE ASSEMBLIES

35.0 FOOT POLES QUARTER POINT OF SPAN	35.0 FOOT POLES CENTER OF SPAN	SPAN LENGTH	40.0 FOOT POLES CENTER OF SPAN	40.0 FOOT POLES QUARTER POINT OF SPAN	UPLIFT FACTOR
5.4	5.0	251.	10.0	10.4	1.7
5.1	4.5	274.	9.5	10.1	2.2
4.7	4.0	295.	9.0	9.7	2.7
4.4	3.5	315.	8.5	9.4	3.2
4.1	3.0	335.	8.0	9.1	3.8
3.8	2.5	354.	7.5	8.8	4.3
3.4	2.0	373.	7.0	8.4	4.9
3.1	1.5	390.	6.5	8.1	5.5
2.8	1.0	408.	6.0	7.8	6.1
2.4	0.5	425.	5.5	7.4	6.7
2.1	LEVEL 0.0	441.	5.0	7.1	7.3
1.8	-0.5	457.	4.5	6.8	7.9
1.4	-1.0	473.	4.0	6.4	8.5
1.1	-1.5	488.	3.5	6.1	9.1
0.8	-2.0	503.	3.0	5.8	9.8
0.4	-2.5	518.	2.5	5.4	10.4
0.1	-3.0	532.	2.0	5.1	11.0
-0.3	-3.5	546.	1.5	4.7	11.7
-0.6	-4.0	560.	1.0	4.4	12.3
-0.9	-4.5	574.	0.5	4.1	13.0
-1.3	-5.0	587.	LEVEL 0.0	3.7	13.7
-1.6	-5.5	600.	-0.5	3.4	14.3
-2.0	-6.0	613.	-1.0	3.0	15.0
-2.3	-6.5	626.	-1.5	2.7	15.7
-2.7	-7.0	639.	-2.0	2.3	16.3
-3.0	-7.5	651.	-2.5	2.0	17.0
-3.3	-8.0	663.	-3.0	1.7	17.7
-3.7	-8.5	675.	-3.5	1.3	18.4
-4.0	-9.0	687.	-4.0	1.0	19.1
-4.4	-9.5	699.	-4.5	0.6	19.8
-4.7	-10.0	710.	-5.0	0.3	20.5

ALL DISTANCES ARE IN FEET

TABLE INCLUDES A 1.0 FOOT STAKING AND CONSTRUCTION TOLERANCE IN ADDITION TO THE BASIC CLEARANCES
TABLE INCLUDES A 1.0 FOOT UPLIFT FACTOR TOLERANCE

THIS TABLE MAY BE USED FOR ANY PHASE CONDUCTOR WHOSE MAXIMUM TEMPERATURE IS 120 DEGREES F OR LESS, AND WHOSE 60 DEGREE F FINAL SAG IN A 525. FOOT SPAN IS LESS THAN OR EQUAL TO 6.5 FEET

STAKING TABLE

TEMP F	0	10	20	30	40	50	60	70	80	90	100
HORIZONTAL TENSION	832	801	771	740	707	675	642	609	576	543	511
SPAN FT.	STRINGING SAG-INCHES										
450	24.	25.	26.	28.	29.	30.	32.	34.	36.	37.	40.
460	26.	27.	28.	29.	30.	32.	33.	35.	37.	39.	42.
470	27.	28.	29.	30.	32.	33.	35.	37.	39.	41.	44.
480	28.	29.	30.	31.	33.	34.	36.	38.	40.	43.	46.
490	29.	30.	31.	33.	34.	36.	38.	40.	42.	44.	48.
500	30.	31.	33.	34.	36.	37.	39.	42.	44.	46.	50.
510	31.	33.	34.	35.	37.	39.	41.	43.	46.	48.	52.
520	33.	34.	35.	37.	39.	40.	42.	45.	47.	50.	54.
525 RS	33.	35.	36.	37.	39.	41.	43.	46.	48.	51.	55.
530	34.	35.	37.	38.	40.	42.	44.	47.	49.	52.	56.
540	35.	37.	38.	40.	42.	44.	46.	48.	51.	54.	58.
550	37.	38.	40.	41.	43.	45.	47.	50.	53.	56.	60.
560	38.	39.	41.	43.	45.	47.	49.	52.	55.	58.	62.
570	39.	41.	43.	44.	46.	49.	51.	54.	57.	60.	64.
580	41.	42.	44.	46.	48.	50.	53.	56.	59.	62.	67.
590	42.	44.	46.	47.	50.	52.	55.	58.	61.	64.	69.
600	43.	45.	47.	49.	51.	54.	56.	60.	63.	67.	71.
610	45.	47.	49.	51.	53.	56.	58.	62.	65.	69.	74.
620	46.	48.	50.	52.	55.	58.	60.	64.	68.	71.	76.
630	48.	50.	52.	54.	57.	59.	62.	66.	70.	73.	79.
640	49.	52.	54.	56.	58.	61.	64.	68.	72.	76.	81.
650	51.	53.	55.	57.	60.	63.	66.	70.	74.	78.	84.
660	53.	55.	57.	59.	62.	65.	68.	72.	77.	81.	86.
670	54.	56.	59.	61.	64.	67.	70.	75.	79.	83.	89.
680	56.	58.	60.	63.	66.	69.	72.	77.	81.	86.	92.
690	58.	60.	62.	65.	68.	71.	75.	79.	84.	88.	94.
700	59.	62.	64.	67.	70.	73.	77.	81.	86.	91.	97.

INITIAL STRINGING SAGS AND TENSIONS

DESIGN POINTS

CREEP IS NOT A FACTOR

TEMP,F	ICE,IN.	WIND,PSF	FINAL SAG, FT.	FINAL TENSION, LB.	INITIAL SAG, FT.	INITIAL TENSION, LB.
15.0	1/4	4	13.89	1339.	13.89	1339.
32.0	1/4		9.93	781.	8.26	939.
60.0		4	8.04	467.	5.33	703.
60.0		6	9.04	553.	6.58	760.
-20.0			3.73	620.	2.59	890.
0.0			4.28	540.	2.77	832.
15.0			4.76	486.	2.93	(787.)
30.0			5.29	436.	3.12	740.
60.0			6.50	355.	3.60	642.
90.0			7.55	306.	4.26	543.
120.0			8.18	282.	5.15	448.
140.0			8.61	268.	5.89	392.
167.0			9.21	251.	7.02	329.
200.0			9.94	233.	8.49	272.
212.0			10.20	227.	9.03	256.

RULING SPAN SAGS AND TENSIONS

CONDUCTOR NO. 2 (6/1) ACSR **DESIGN RULING SPAN** 325 **FT. DESIGN TENSION** 1500 **LBS.**

RECOMMENDED FOR USE WITH RULING SPANS FROM 300 **FT. TO** 425 **FT.** MEDIUM **LOADING DISTRICT**

	PHASE	NEUTRAL
CONDUCTOR DESC.	NO. 2(6/1) ACSR	NO. 2(6/1) ACSR
MAX. OPERATING TEMP.	120. DEGREES F	120.DEGREES F
BASIC GROUND CLEAR.	20.0 FEET	18.0 FEET
DESIGN TENSION	1292. LBS (45.3 %)	1292. LBS (45.3 %)

325. FOOT RULING SPAN MEDIUM LOADING DISTRICT

FOR USE WITH A1,B1,AND C1 TYPE ASSEMBLIES

35.0 FOOT POLES QUARTER POINT OF SPAN	35.0 FOOT POLES CENTER OF SPAN	SPAN LENGTH	40.0 FOOT POLES CENTER OF SPAN	40.0 FOOT POLES QUARTER POINT OF SPAN	UPLIFT FACTOR
5.4	5.0	244.	10.0	10.4	2.0
5.0	4.5	268.	9.5	10.0	2.7
4.7	4.0	289.	9.0	9.7	3.3
4.4	3.5	309.	8.5	9.4	3.9
4.1	3.0	328.	8.0	9.1	4.5
3.7	2.5	347.	7.5	8.7	5.2
3.4	2.0	365.	7.0	8.4	5.8
3.1	1.5	382.	6.5	8.1	6.5
2.7	1.0	399.	6.0	7.7	7.1
2.4	0.5	415.	5.5	7.4	7.8
2.1	LEVEL 0.0	431.	5.0	7.1	8.5
1.7	-0.5	447.	4.5	6.7	9.2
1.4	-1.0	462.	4.0	6.4	9.9
1.1	-1.5	477.	3.5	6.1	10.6
0.7	-2.0	492.	3.0	5.7	11.4
0.4	-2.5	506.	2.5	5.4	12.1
0.0	-3.0	520.	2.0	5.0	12.8
-0.3	-3.5	533.	1.5	4.7	13.5
-0.6	-4.0	547.	1.0	4.4	14.3
-1.0	-4.5	560.	0.5	4.0	15.0
-1.3	-5.0	573.	LEVEL 0.0	3.7	15.8
-1.7	-5.5	586.	-0.5	3.3	16.5
-2.0	-6.0	598.	-1.0	3.0	17.3
-2.3	-6.5	611.	-1.5	2.7	18.1
-2.7	-7.0	623.	-2.0	2.3	18.8
-3.0	-7.5	635.	-2.5	2.0	19.6
-3.4	-8.0	647.	-3.0	1.6	20.4
-3.7	-8.5	658.	-3.5	1.3	21.2
-4.1	-9.0	670.	-4.0	0.9	21.9
-4.4	-9.5	681.	-4.5	0.6	22.7
-4.8	-10.0	692.	-5.0	0.2	23.5

ALL DISTANCES ARE IN FEET

TABLE INCLUDES A 1.0 FOOT STAKING AND CONSTRUCTION TOLERANCE IN ADDITION TO THE BASIC CLEARANCES
TABLE INCLUDES A 1.0 FOOT UPLIFT FACTOR TOLERANCE

THIS TABLE MAY BE USED FOR ANY PHASE CONDUCTOR WHOSE MAXIMUM TEMPERATURE IS 120 DEGREES F OR LESS, AND WHOSE 60 DEGREE F FINAL SAG IN A 325. FOOT SPAN IS LESS THAN OR EQUAL TO 2.7 FEET

STAKING TABLE

STRINGING SAG-INCHES

TEMP F	0	10	20	30	40	50	60	70	80	90	100
HORIZONTAL TENSION	961	914	866	819	770	720	671	622	572	523	480
SPAN FT.											
200	6.	6.	6.	7.	7.	8.	8.	9.	10.	10.	12.
210	6.	7.	7.	7.	8.	8.	9.	10.	11.	12.	13.
220	7.	7.	8.	8.	9.	9.	10.	11.	12.	13.	14.
230	8.	8.	8.	9.	9.	10.	11.	12.	13.	11.	15.
240	8.	9.	9.	10.	10.	11.	12.	13.	14.	15.	17.
250	9.	9.	10.	10.	11.	12.	13.	14.	15.	16.	18.
260	10.	10.	11.	11.	12.	13.	14.	15.	16.	18.	20.
270	10.	11.	12.	12.	13.	14.	15.	16.	18.	19.	21.
280	11.	12.	12.	13.	14.	15.	16.	18.	19.	21.	23.
290	12.	13.	13.	14.	15.	16.	17.	19.	20.	22.	24.
300	13.	14.	14.	15.	16.	17.	18.	20.	22.	24.	26.
310	14.	14.	15.	16.	17.	18.	20.	21.	23.	25.	28.
320	15.	15.	16.	17.	18.	20.	21.	23.	25.	27.	30.
325 RS	15.	16.	17.	18.	19.	20.	22.	24.	26.	28.	31.
330	16.	16.	17.	18.	20.	21.	22.	24.	26.	29.	32.
340	16.	17.	18.	19.	21.	22.	24.	26.	28.	30.	34.
350	17.	18.	19.	20.	22.	23.	25.	27.	30.	32.	36.
360	18.	20.	21.	22.	23.	25.	26.	29.	31.	34.	38.
370	20.	21.	22.	23.	25.	26.	28.	31.	33.	36.	40.
380	21.	22.	23.	24.	26.	28.	29.	32.	35.	38.	42.
390	22.	23.	24.	25.	27.	29.	31.	34.	37.	40.	44.
400	23.	24.	25.	27.	29.	31.	33.	36.	39.	42.	47.
410	24.	25.	27.	28.	30.	32.	34.	38.	41.	14.	49.
420	25.	27.	28.	30.	32.	34.	36.	39.	43.	46.	51.
430	26.	28.	29.	31.	33.	35.	38.	41.	45.	18.	54.

INITIAL STRINGING SAGS AND TENSIONS

DESIGN POINTS
CREEP IS NOT A FACTOR

TEMP,F	ICE,IN.	WIND,PSF	FINAL SAG, FT.	FINAL TENSION, LB.	INITIAL SAG, FT.	INITIAL TENSION, LB.
15.0	1/4	4	5.95	1292.	5.95	1292.
32.0	1/4		4.18	846.	3.69	958.
60.0		4	3.43	537.	2.56	718.
60.0		6	3.97	608.	3.15	765.
-20.0			1.27	950.	1.15	1050.
0.0			1.48	813.	1.25	961.
15.0			1.69	(713.)	1.35	891.
30.0			1.95	618.	1.47	819.
60.0			2.66	454.	1.80	671.
90.0			3.59	336.	2.31	523.
120.0			4.53	266.	3.07	393.
140.0			4.81	251.	3.69	326.
167.0			5.20	232.	4.60	262.
200.0			5.68	213.	5.63	215.
212.0			5.86	206.	5.80	208.

RULING SPAN SAGS AND TENSIONS

CONDUCTOR NO. 2 (6/1) ACSR **DESIGN RULING SPAN** 425 **FT. DESIGN TENSION** 1600 **LBS.**

RECOMMENDED FOR USE WITH RULING SPANS FROM 400 **FT. TO** 525 **FT.** MEDIUM **LOADING DISTRICT**

	PHASE	NEUTRAL
CONDUCTOR DESC.	NO. 2(6/1) ACSR	NO. 2(6/1) ACSR
MAX. OPERATING TEMP.	120. DEGREES F	120.DEGREES F
BASIC GROUND CLEAR.	20.0 FEET	18.0 FEET
DESIGN TENSION	1458. LBS (51.2 %)	1458. LBS (51.2 %)

425. FOOT RULING SPAN MEDIUM LOADING DISTRICT

FOR USE WITH A1,B1,AND C1 TYPE ASSEMBLIES

35.0 FOOT POLES QUARTER POINT OF SPAN	35.0 FOOT POLES CENTER OF SPAN	SPAN LENGTH	40.0 FOOT POLES CENTER OF SPAN	40.0 FOOT POLES QUARTER POINT OF SPAN	UPLIFT FACTOR
5.4	5.0	250.	10.0	10.4	2.0
5.1	4.5	272.	9.5	10.1	2.6
4.7	4.0	293.	9.0	9.7	3.1
4.4	3.5	313.	8.5	9.4	3.7
4.1	3.0	333.	8.0	9.1	4.3
3.8	2.5	352.	7.5	8.8	4.9
3.4	2.0	370.	7.0	8.4	5.6
3.1	1.5	388.	6.5	8.1	6.2
2.8	1.0	405.	6.0	7.8	6.9
2.4	0.5	422.	5.5	7.4	7.5
2.1	LEVEL 0.0	438.	5.0	7.1	8.2
1.8	-0.5	454.	4.5	6.8	8.9
1.4	-1.0	469.	4.0	6.4	9.6
1.1	-1.5	485.	3.5	6.1	10.3
0.7	-2.0	499.	3.0	5.7	11.0
0.4	-2.5	514.	2.5	5.4	11.7
0.1	-3.0	528.	2.0	5.1	12.4
-0.3	-3.5	542.	1.5	4.7	13.1
-0.6	-4.0	556.	1.0	4.4	13.8
-1.0	-4.5	569.	0.5	4.0	14.6
-1.3	-5.0	583.	LEVEL 0.0	3.7	15.3
-1.6	-5.5	596.	-0.5	3.4	16.0
-2.0	-6.0	608.	-1.0	3.0	16.8
-2.3	-6.5	621.	-1.5	2.7	17.5
-2.7	-7.0	633.	-2.0	2.3	18.3
-3.0	-7.5	646.	-2.5	2.0	19.0
-3.4	-8.0	658.	-3.0	1.6	19.8
-3.7	-8.5	670.	-3.5	1.3	20.6
-4.0	-9.0	681.	-4.0	1.0	21.3
-4.4	-9.5	693.	-4.5	0.6	22.1
-4.7	-10.0	705.	-5.0	0.3	22.9

ALL DISTANCES ARE IN FEET

TABLE INCLUDES A 1.0 FOOT STAKING AND CONSTRUCTION TOLERANCE IN ADDITION TO THE BASIC CLEARANCES
TABLE INCLUDES A 1.0 FOOT UPLIFT FACTOR TOLERANCE

THIS TABLE MAY BE USED FOR ANY PHASE CONDUCTOR WHOSE MAXIMUM TEMPERATURE IS 120 DEGREES F OR LESS, AND WHOSE 60 DEGREE F FINAL SAG IN A 425. FOOT SPAN IS LESS THAN OR EQUAL TO 4.3 FEET

STAKING TABLE

TEMP F	0	10	20	30	40	50	60	70	80	90	100
HORIZONTAL TENSION	1016	971	927	882	835	788	741	695	648	602	560
SPAN FT.	STRINGING SAG-INCHES										
320	14.	15.	15.	16.	17.	18.	19.	20.	22.	23.	25.
330	15.	15.	16.	17.	18.	19.	20.	22.	23.	25.	27.
340	16.	16.	17.	18.	19.	20.	21.	23.	25.	26.	29.
350	17.	17.	18.	19.	20.	21.	23.	24.	26.	28.	30.
360	17.	18.	19.	20.	21.	23.	24.	26.	28.	29.	32.
370	18.	19.	20.	21.	23.	24.	25.	27.	29.	31.	34.
380	19.	20.	21.	22.	24.	25.	27.	29.	31.	33.	36.
390	21.	22.	23.	24.	25.	27.	28.	30.	32.	35.	38.
400	22.	23.	24.	25.	26.	28.	30.	32.	34.	36.	40.
410	23.	24.	25.	26.	28.	29.	31.	33.	36.	38.	42.
420	24.	25.	26.	27.	29.	31.	33.	35.	38.	40.	44.
425 RS	24.	26.	27.	28.	30.	32.	33.	36.	39.	41.	45.
430	25.	26.	27.	29.	31.	32.	34.	37.	39.	42.	46.
440	26.	27.	29.	30.	32.	34.	36.	39.	41.	44.	48.
450	27.	29.	30.	31.	33.	35.	37.	40.	43.	46.	50.
460	29.	30.	31.	33.	35.	37.	39.	42.	45.	48.	52.
470	30.	31.	33.	34.	36.	39.	41.	44.	47.	50.	55.
480	31.	33.	34.	36.	38.	40.	43.	46.	49.	52.	57.
490	32.	34.	36.	37.	40.	42.	44.	48.	51.	55.	59.
500	34.	35.	37.	39.	41.	44.	46.	50.	53.	57.	62.
510	35.	37.	39.	40.	43.	46.	48.	52.	55.	59.	64.
520	36.	38.	40.	42.	45.	47.	50.	54.	58.	62.	67.
530	38.	40.	42.	44.	46.	49.	52.	56.	60.	64.	70.
540	39.	41.	43.	45.	48.	51.	54.	58.	62.	66.	72.
550	41.	43.	45.	47.	50.	53.	56.	60.	65.	69.	75.
560	42.	44.	47.	49.	52.	55.	58.	62.	67.	71.	78.
570	44.	46.	48.	50.	54.	57.	60.	65.	69.	74.	80.
580	45.	48.	50.	52.	56.	59.	62.	67.	72.	77.	83.
590	47.	49.	52.	54.	57.	61.	64.	69.	74.	79.	86.
600	49.	51.	53.	56.	59.	63.	67.	72.	77.	82.	89.

INITIAL STRINGING SAGS AND TENSIONS

DESIGN POINTS TEMP,F	ICE,IN.	WIND,PSF	FINAL SAG, FT.	FINAL TENSION, LB.	INITIAL SAG, FT.	INITIAL TENSION, LB.
CREEP IS NOT A FACTOR						
15.0	1/4	4	9.02	1458.	9.02	1458.
32.0	1/4		6.52	927.	5.66	1068.
60.0		4	5.41	582.	3.92	803.
60.0		6	6.15	671.	4.78	862.
-20.0			2.23	924.	1.87	1101.
0.0			2.60	794.	2.03	1016.
15.0			2.94	702.	2.17	(950.)
30.0			3.34	617.	2.34	882.
60.0			4.35	475.	2.78	741.
90.0			5.53	373.	3.43	602.
120.0			6.55	315.	4.33	477.
140.0			6.89	300.	5.05	408.
167.0			7.35	281.	6.12	337.
200.0			7.93	260.	7.43	278.
212.0			8.11	254.	7.89	262.

RULING SPAN SAGS AND TENSIONS

CONDUCTOR NO. 2 (6/1) ACSR DESIGN RULING SPAN 525 FT. DESIGN TENSION 1600 LBS.

RECOMMENDED FOR USE WITH RULING SPANS FROM 500 FT. TO 625 FT. MEDIUM LOADING DISTRICT

	PHASE	NEUTRAL
CONDUCTOR DESC.	NO. 2(6/1) ACSR	NO. 2(6/1) ACSR
MAX. OPERATING TEMP.	120. DEGREES F	120.DEGREES F
BASIC GROUND CLEAR.	20.0 FEET	18.0 FEET
DESIGN TENSION	1582 LBS (55.5 %)	1582 LBS (55.5 %)

525. FOOT RULING SPAN MEDIUM LOADING DISTRICT

FOR USE WITH A1,B1,AND C1 TYPE ASSEMBLIES

35.0 FOOT POLES QUARTER POINT OF SPAN	35.0 FOOT POLES CENTER OF SPAN	SPAN LENGTH	40.0 FOOT POLES CENTER OF SPAN	40.0 FOOT POLES QUARTER POINT OF SPAN	UPLIFT FACTOR
5.4	5.0	247.	10.0	10.4	1.9
5.1	4.5	270.	9.5	10.1	2.5
4.7	4.0	291.	9.0	9.7	3.1
4.4	3.5	311.	8.5	9.4	3.7
4.1	3.0	331.	8.0	9.1	4.3
1.7	2.5	349.	7.5	8.7	4.9
3.4	2.0	367.	7.0	8.4	5.5
3.1	1.5	385.	6.5	8.1	6.1
2.8	1.0	402.	6.0	7.8	6.8
2.4	0.5	419.	5.5	7.4	7.4
2.1	LEVEL 0.0	435.	5.0	7.1	8.1
0.8	-0.5	451.	4.5	5.8	8.8
0.3	-1.0	466.	4.0	5.3	9.5
-0.1	-1.5	482.	3.5	4.9	10.1
-0.5	-2.0	497.	3.0	4.5	10.8
-0.9	-2.5	511.	2.5	4.1	11.5
-1.3	-3.0	525.	2.0	3.7	12.2
-1.7	-3.5	539.	1.5	3.3	12.9
-2.1	-4.0	552.	1.0	2.9	13.6
-2.5	-4.5	565.	0.5	2.5	14.3
-1.3	-5.0	578.	LEVEL 0.0	3.7	15.0
-1.6	-5.5	591.	-0.5	3.4	15.8
-2.0	-6.0	603.	-1.0	3.0	16.5
-2.3	-6.5	616.	-1.5	2.7	17.2
-2.7	-7.0	628.	-2.0	2.3	18.0
-1.0	-7.5	640.	-2.5	2.0	18.7
-1.4	-8.0	652.	-3.0	1.6	19.4
-3.7	-8.5	664.	-3.5	1.3	20.2
-4.1	-9.0	676.	-4.0	0.9	20.9
-4.4	-9.5	687.	-4.5	0.6	21.7
-4.8	-10.0	698.	-5.0	0.2	22.4

ALL DISTANCES ARE IN FEET

TABLE INCLUDES A 1.0 FOOT STAKING AND CONSTRUCTION TOLERANCE IN ADDITION TO THE BASIC CLEARANCES

TABLE INCLUDES A 1.0 FOOT UPLIFT FACTOR TOLERANCE

THIS TABLE MAY BE USED FOR ANY PHASE CONDUCTOR WHOSE MAXIMUM TEMPERATURE IS 120 DEGREES F OR LESS, AND WHOSE 60 DEGREE F FINAL SAG IN A 525. FOOT SPAN IS LESS THAN OR EQUAL TO 6.8 FEET

STAKING TABLE

STRINGING SAG-INCHES

TEMP F	0	10	20	30	40	50	60	70	80	90	100
HORIZONTAL TENSION	1014	971	927	884	839	795	751	708	665	623	585
SPAN FT.											
450	27.	29.	30.	31.	33.	35.	37.	39.	42.	45.	48.
460	29.	30.	31.	33.	35.	37.	39.	41.	44.	47.	50.
470	30.	31.	33.	34.	36.	38.	40.	43.	46.	49.	52.
480	31.	31.	34.	36.	38.	40.	42.	45.	48.	51.	54.
490	32.	34.	36.	37.	39.	42.	44.	47.	50.	53.	57.
500	34.	35.	37.	39.	41.	43.	46.	49.	52.	55.	59.
510	35.	37.	39.	40.	43.	45.	47.	51.	54.	57.	61.
520	37.	38.	40.	42.	44.	47.	49.	53.	56.	59.	64.
525 RS	37.	39.	41.	43.	45.	48.	50.	54.	57.	61.	65.
530	38.	40.	42.	44.	46.	49.	51.	55.	58.	62.	66.
540	39.	41.	43.	45.	48.	51.	53.	57.	60.	64.	69.
550	41.	43.	45.	47.	50.	52.	55.	59.	63.	67.	71.
560	42.	44.	47.	49.	51.	54.	57.	61.	65.	69.	74.
570	44.	46.	48.	50.	53.	56.	59.	63.	67.	71.	77.
580	45.	48.	50.	52.	55.	58.	61.	66.	70.	74.	79.
590	47.	49.	52.	54.	57.	60.	64.	68.	72.	77.	82.
600	49.	51.	53.	56.	59.	62.	66.	70.	75.	79.	85.
610	50.	53.	55.	58.	61.	64.	68.	73.	77.	82.	88.
620	52.	54.	57.	60.	63.	67.	70.	75.	80.	85.	91.
630	54.	56.	59.	62.	65.	69.	72.	77.	82.	87.	94.
640	55.	58.	61.	63.	67.	71.	75.	80.	85.	90.	97.
650	57.	60.	63.	65.	69.	73.	77.	82.	88.	93.	100.
660	59.	62.	65.	68.	71.	75.	79.	85.	90.	96.	103.
670	61.	64.	67.	70.	74.	78.	82.	88.	93.	99.	106.
680	62.	66.	69.	72.	76.	80.	84.	90.	96.	102.	109.
690	64.	67.	71.	74.	78.	82.	87.	93.	99.	105.	112.
700	66.	69.	73.	76.	80.	85.	89.	96.	102.	108.	116.

INITIAL STRINGING SAGS AND TENSIONS

CREEP IS NOT A FACTOR

DESIGN POINTS TEMP,F	ICE,IN.	WIND,PSF	FINAL SAG, FT.	FINAL TENSION, LB.	INITIAL SAG, FT.	INITIAL TENSION, LB.
15.0	1/4	4	12.70	1582.	12.70	1582.
32.0	1/4		9.50	971.	8.15	1132.
60.0		4	8.08	595.	5.76	834.
60.0		6	8.99	700.	6.92	909.
-20.0			3.75	839.	2.87	1097.
0.0			4.35	724.	3.10	1014.
15.0			4.88	645.	3.31	(950.)
30.0			5.47	576.	3.56	884.
60.0			6.79	464.	4.19	751.
90.0			8.19	384.	5.05	623.
120.0			9.15	344.	6.16	511.
140.0			9.54	330.	7.02	439.
167.0			10.08	313.	8.24	382.
200.0			10.75	293.	9.74	324.
212.0			10.99	287.	10.27	307.

RULING SPAN SAGS AND TENSIONS

CONDUCTOR 1/0 (6/1) ACSR DESIGN RULING SPAN 325 FT. DESIGN TENSION 1925 LBS.

RECOMMENDED FOR USE WITH RULING SPANS FROM 300 FT. TO 425 FT. MEDIUM LOADING DISTRICT

	PHASE	NEUTRAL
CONDUCTOR DESC.	1/0 (6/1) ACSR	1/0 (6/1) ACSR
MAX. OPERATING TEMP.	120. DEGREES F	120. DEGREES F
BASIC GROUND CLEAR.	20.0 FEET	18.0 FEET
DESIGN TENSION	1720. LBS (39.3 %)	1720. LBS (39.3 %)

325. FOOT RULING SPAN MEDIUM LOADING DISTRICT

FOR USE WITH A1,B1,AND C1 TYPE ASSEMBLIES

35.0 FOOT POLES QUARTER POINT OF SPAN	35.0 FOOT POLES CENTER OF SPAN	SPAN LENGTH	40.0 FOOT POLES CENTER OF SPAN	40.0 FOOT POLES QUARTER POINT OF SPAN	UPLIFT FACTOR
5.4	5.0	240.	10.0	10.4	2.3
5.0	4.5	266.	9.5	10.0	3.0
4.7	4.0	286.	9.0	9.7	3.6
4.4	3.5	306.	8.5	9.4	4.3
4.1	3.0	325.	8.0	9.1	5.0
3.7	2.5	343.	7.5	8.7	5.6
3.4	2.0	361.	7.0	8.4	6.3
3.1	1.5	378.	6.5	8.1	7.1
2.7	1.0	395.	6.0	7.7	7.8
2.4	0.5	411.	5.5	7.4	8.5
2.1	LEVEL 0.0	426.	5.0	7.1	9.3
1.7	-0.5	442.	4.5	6.7	10.0
1.4	-1.0	457.	4.0	6.4	10.8
1.1	-1.5	471.	3.5	6.1	11.5
0.7	-2.0	486.	3.0	5.7	12.3
0.4	-2.5	500.	2.5	5.4	13.1
0.0	-3.0	513.	2.0	5.0	13.9
-0.3	-3.5	527.	1.5	4.7	14.7
-0.6	-4.0	540.	1.0	4.4	15.5
-1.0	-4.5	553.	0.5	4.0	16.3
-1.3	-5.0	566.	LEVEL 0.0	3.7	17.1
-1.7	-5.5	579.	-0.5	3.3	17.9
-2.0	-6.0	591.	-1.0	3.0	18.7
-2.4	-6.5	603.	-1.5	2.6	19.5
-2.7	-7.0	615.	-2.0	2.3	20.3
-3.1	-7.5	627.	-2.5	1.9	21.2
-3.4	-8.0	639.	-3.0	1.6	22.0
-3.7	-8.5	650.	-3.5	1.2	22.8
-4.1	-9.0	661.	-4.0	0.9	23.7
-4.4	-9.5	673.	-4.5	0.6	24.5
-4.8	-10.0	684.	-5.0	0.2	25.4

ALL DISTANCES ARE IN FEET

TABLE INCLUDES A 1.0 FOOT STAKING AND CONSTRUCTION TOLERANCE IN ADDITION TO THE BASIC CLEARANCES
TABLE INCLUDES A 1.0 FOOT UPLIFT FACTOR TOLERANCE

THIS TABLE MAY BE USED FOR ANY PHASE CONDUCTOR WHOSE MAXIMUM TEMPERATURE IS 120 DEGREES F OR LESS, AND WHOSE 60 DEGREE F FINAL SAG IN A 325. FOOT SPAN IS LESS THAN OR EQUAL TO 2.8 FEET

STAKING TABLE

TEMP F	0	10	20	30	40	50	60	70	80	90	100
HORIZONTAL TENSION	1393	1323	1254	1184	1113	1042	971	903	835	767	708
SPAN FT.	STRINGING SAG-INCHES										
200	6.	7.	7.	7.	8.	8.	9.	10.	11.	11.	12.
210	7.	7.	8.	8.	9.	9.	10.	11.	12.	13.	14.
220	8.	8.	8.	9.	10.	10.	11.	12.	13.	14.	15.
230	8.	9.	9.	10.	10.	11.	12.	13.	14.	15.	17.
240	9.	10.	10.	11.	11.	12.	13.	14.	15.	16.	18.
250	10.	10.	11.	12.	12.	13.	14.	15.	17.	18.	20.
260	11.	11.	12.	12.	13.	14.	15.	17.	18.	19.	21.
270	11.	12.	13.	13.	14.	15.	16.	18.	19.	21.	23.
280	12.	13.	14.	14.	15.	17.	18.	19.	21.	22.	24.
290	13.	14.	15.	15.	17.	18.	19.	21.	22.	24.	26.
300	14.	15.	16.	17.	18.	19.	20.	22.	24.	26.	28.
310	15.	16.	17.	18.	19.	20.	22.	23.	25.	27.	30.
320	16.	17.	18.	19.	20.	22.	23.	25.	27.	29.	32.
325 RS	17.	18.	18.	19.	21.	22.	24.	26.	28.	30.	33.
330	17.	18.	19.	20.	22.	23.	24.	27.	29.	31.	34.
340	18.	19.	20.	21.	23.	24.	26.	28.	31.	33.	36.
350	19.	20.	21.	23.	24.	26.	28.	30.	32.	35.	38.
360	20.	21.	23.	24.	26.	27.	29.	32.	34.	37.	40.
370	21.	23.	24.	25.	27.	29.	31.	33.	36.	39.	43.
380	23.	24.	25.	27.	29.	30.	32.	35.	38.	41.	45.
390	24.	25.	27.	28.	30.	32.	34.	37.	40.	43.	48.
400	25.	27.	28.	29.	32.	34.	36.	39.	42.	45.	50.
410	26.	28.	29.	31.	33.	35.	38.	41.	44.	48.	52.
420	28.	29.	31.	32.	35.	37.	40.	43.	47.	50.	55.
430	29.	31.	32.	34.	37.	39.	42.	45.	49.	53.	58.

INITIAL STRINGING SAGS AND TENSIONS

DESIGN POINTS

CREEP IS NOT A FACTOR

TEMP,F	ICE,IN.	WIND,PSF	FINAL SAG, FT.	FINAL TENSION, LB.	INITIAL SAG, FT.	INITIAL TENSION, LB.
15.0	1/4	4	5.06	1720.	5.06	1720.
32.0	1/4		3.79	1211.	3.41	1345.
60.0		4	3.29	790.	2.54	1024.
60.0		6	3.72	874.	3.02	1079.
-20.0			1.31	1462.	1.26	1528.
0.0			1.54	1249.	1.38	1393.
15.0			1.75	(1095.)	1.49	1290.
30.0			2.02	950.	1.62	1184.
60.0			2.75	699.	1.98	971.
90.0			3.69	520.	2.50	767.
120.0			4.69	410.	3.24	592.
140.0			4.97	387.	3.83	501.
167.0			5.36	359.	4.67	411.
200.0			5.84	329.	5.68	338.
212.0			6.01	320.	5.86	328.

RULING SPAN SAGS AND TENSIONS

CONDUCTOR 1/0 (6/1) ACSR **DESIGN RULING SPAN** 425 **FT. DESIGN TENSION** 2125 **LBS.**

RECOMMENDED FOR USE WITH RULING SPANS FROM 400 **FT. TO** 525 **FT.** MEDIUM **LOADING DISTRICT**

	PHASE	NEUTRAL
CONDUCTOR DESC.	1/0 (6/1) ACSR	1/0 (6/1) ACSR
MAX. OPERATING TEMP.	120. DEGREES F	120.DEGREES F
BASIC GROUND CLEAR.	20.0 FEET	18.0 FEET
DESIGN TENSION	1922. LBS (43.9 %)	1922. LBS (43.9 %)

425. FOOT RULING SPAN MEDIUM LOADING DISTRICT

FOR USE WITH A1,B1,AND C1 TYPE ASSEMBLIES

35.0 FOOT POLES QUARTER POINT OF SPAN	35.0 FOOT POLES CENTER OF SPAN	SPAN LENGTH	40.0 FOOT POLES CENTER OF SPAN	40.0 FOOT POLES QUARTER POINT OF SPAN	UPLIFT FACTOR
5.4	5.0	248.	10.0	10.4	2.3
5.1	4.5	271.	9.5	10.1	2.9
4.7	4.0	292.	9.0	9.7	3.5
4.4	3.5	312.	8.5	9.4	4.2
4.1	3.0	332.	8.0	9.1	4.9
3.8	2.5	350.	7.5	8.8	5.6
3.4	2.0	368.	7.0	8.4	6.2
3.1	1.5	386.	6.5	8.1	7.0
2.8	1.0	403.	6.0	7.8	7.7
2.4	0.5	420.	5.5	7.4	8.4
2.1	LEVEL 0.0	436.	5.0	7.1	9.1
1.8	-0.5	452.	4.5	6.8	9.9
1.4	-1.0	467.	4.0	6.4	10.6
1.1	-1.5	482.	3.5	6.1	11.4
0.7	-2.0	497.	3.0	5.7	12.2
0.4	-2.5	511.	2.5	5.4	13.0
0.1	-3.0	526.	2.0	5.1	13.7
-0.3	-3.5	539.	1.5	4.7	14.5
-0.6	-4.0	553.	1.0	4.4	15.3
-1.0	-4.5	566.	0.5	4.0	16.1
-1.3	-5.0	580.	LEVEL 0.0	3.7	16.9
-1.6	-5.5	593.	-0.5	3.4	17.7
-2.0	-6.0	605.	-1.0	3.0	18.6
-2.3	-6.5	618.	-1.5	2.7	19.4
-2.7	-7.0	630.	-2.0	2.3	20.2
-3.0	-7.5	642.	-2.5	2.0	21.0
-3.4	-8.0	654.	-3.0	1.6	21.9
-3.7	-8.5	666.	-3.5	1.3	22.7
-4.1	-9.0	678.	-4.0	0.9	23.5
-4.4	-9.5	689.	-4.5	0.6	24.4
-4.7	-10.0	701.	-5.0	0.3	25.2

ALL DISTANCES ARE IN FEET

TABLE INCLUDES A 1.0 FOOT STAKING AND CONSTRUCTION TOLERANCE IN ADDITION TO THE BASIC CLEARANCES
TABLE INCLUDES A 1.0 FOOT UPLIFT FACTOR TOLERANCE

THIS TABLE MAY BE USED FOR ANY PHASE CONDUCTOR WHOSE MAXIMUM TEMPERATURE IS 120 DEGREES F OR LESS, AND WHOSE 60 DEGREE F FINAL SAG IN A 425. FOOT SPAN IS LESS THAN OR EQUAL TO 4.4 FEET

STAKING TABLE

TEMP F	0	10	20	30	40	50	60	70	80	90	100
HORIZONTAL TENSION	1458	1391	1324	1258	1191	1124	1057	993	929	866	810
SPAN FT.					STRINGING SAG-INCHES						
320	15.	16.	17.	18.	19.	20.	21.	23.	24.	26.	28.
330	16.	17.	18.	19.	20.	21.	22.	24.	26.	27.	30.
340	17.	18.	19.	20.	21.	23.	24.	26.	27.	29.	31.
350	18.	19.	20.	21.	23.	24.	25.	27.	29.	31.	33.
360	19.	20.	21.	22.	24.	25.	27.	29.	31.	33.	35.
370	20.	22.	23.	24.	25.	27.	28.	30.	32.	34.	37.
380	22.	23.	24.	25.	27.	28.	30.	32.	34.	36.	39.
390	23.	24.	25.	26.	28.	30.	31.	34.	36.	38.	41.
400	24.	25.	26.	28.	29.	31.	33.	35.	38.	40.	43.
410	25.	26.	28.	29.	31.	33.	35.	37.	40.	42.	46.
420	26.	28.	29.	31.	33.	34.	36.	39.	42.	44.	48.
425 RS	27.	28.	30.	31.	33.	35.	37.	40.	43.	45.	49.
430	28.	29.	31.	32.	34.	36.	38.	41.	44.	47.	50.
440	29.	30.	32.	34.	36.	38.	40.	43.	46.	49.	53.
450	30.	32.	33.	35.	37.	40.	42.	45.	48.	51.	55.
460	32.	33.	35.	37.	39.	41.	44.	47.	50.	53.	57.
470	33.	35.	37.	38.	41.	43.	46.	49.	52.	56.	60.
480	34.	36.	38.	40.	42.	45.	48.	51.	55.	58.	63.
490	36.	38.	40.	42.	44.	47.	50.	53.	57.	60.	65.
500	37.	39.	41.	43.	46.	49.	52.	55.	59.	63.	68.
510	39.	41.	43.	45.	48.	51.	54.	58.	62.	65.	71.
520	40.	43.	45.	47.	50.	53.	56.	60.	64.	68.	73.
530	42.	44.	46.	49.	52.	55.	58.	62.	66.	71.	76.
540	44.	46.	48.	51.	54.	57.	60.	65.	69.	73.	79.
550	45.	48.	50.	52.	56.	59.	62.	67.	72.	76.	82.
560	47.	49.	52.	54.	58.	61.	65.	69.	74.	79.	85.
570	49.	51.	54.	56.	60.	63.	67.	72.	77.	82.	88.
580	50.	53.	56.	58.	62.	66.	69.	74.	80.	85.	91.
590	52.	55.	58.	60.	64.	68.	72.	77.	82.	88.	95.
600	54.	57.	60.	62.	66.	70.	74.	80.	85.	91.	98.

INITIAL STRINGING SAGS AND TENSIONS

DESIGN POINTS

CREEP IS NOT A FACTOR

TEMP,F	ICE,IN.	WIND,PSF	FINAL SAG, FT.	FINAL TENSION, LB.	INITIAL SAG, FT.	INITIAL TENSION, LB.
15.0	1/4	4	7.75	1922.	7.75	1922.
32.0	1/4		5.93	1322.	5.29	1480.
60.0		4	5.16	861.	3.94	1128.
60.0		6	5.76	967.	4.64	1199.
-20.0			2.28	1439.	2.07	1587.
0.0			2.65	1237.	2.25	1458.
15.0			3.00	(1095.)	2.41	1359.
30.0			3.40	964.	2.61	1258.
60.0			4.41	744.	3.10	1057.
90.0			5.59	588.	3.79	866.
120.0			6.80	483.	4.69	700.
140.0			7.21	456.	5.38	610.
167.0			7.68	428.	6.38	515.
200.0			8.25	398.	7.60	432.
212.0			8.46	389.	8.03	409.

RULING SPAN SAGS AND TENSIONS

CONDUCTOR 1/0 (6/1) ACSR DESIGN RULING SPAN 525 FT. DESIGN TENSION 2125 LBS.

RECOMMENDED FOR USE WITH RULING SPANS FROM 500 FT. TO 625 FT. MEDIUM LOADING DISTRICT

	PHASE	NEUTRAL
CONDUCTOR DESC.	1/0 (6/1) ACSR	1/0 (6/1) ACSR
MAX. OPERATING TEMP.	120. DEGREES F	120. DEGREES F
BASIC GROUND CLEAR.	20.0 FEET	18.0 FEET
DESIGN TENSION	2108 LBS (48.1 %)	2108 LBS (48.1 %)

525. FOOT RULING SPAN MEDIUM LOADING DISTRICT

FOR USE WITH A1,B1,AND C1 TYPE ASSEMBLIES

35.0 FOOT POLES QUARTER POINT OF SPAN	35.0 FOOT POLES CENTER OF SPAN	SPAN LENGTH	40.0 FOOT POLES CENTER OF SPAN	40.0 FOOT POLES QUARTER POINT OF SPAN	UPLIFT FACTOR
5.4	5.0	252.	10.0	10.4	2.3
5.1	4.5	275.	9.5	10.1	2.9
4.7	4.0	297.	9.0	9.7	3.5
4.4	3.5	317.	8.5	9.4	4.1
4.1	3.0	337.	8.0	9.1	4.8
3.8	2.5	356.	7.5	8.8	5.5
3.4	2.0	375.	7.0	8.4	6.2
3.1	1.5	393.	6.5	8.1	6.9
2.8	1.0	410.	6.0	7.8	7.6
2.4	0.5	427.	5.5	7.4	8.3
2.1	LEVEL 0.0	444.	5.0	7.1	9.1
1.8	-0.5	460.	4.5	6.8	9.8
1.4	-1.0	476.	4.0	6.4	10.6
1.1	-1.5	491.	3.5	6.1	11.3
0.8	-2.0	506.	3.0	5.8	12.1
0.4	-2.5	521.	2.5	5.4	12.9
0.1	-3.0	536.	2.0	5.1	13.7
-0.3	-3.5	550.	1.5	4.7	14.4
-0.6	-4.0	564.	1.0	4.4	15.2
-0.9	-4.5	578.	0.5	4.1	16.0
-1.3	-5.0	591.	LEVEL 0.0	3.7	16.9
-1.6	-5.5	604.	-0.5	3.4	17.7
-2.0	-6.0	617.	-1.0	3.0	18.5
-2.3	-6.5	630.	-1.5	2.7	19.3
-2.6	-7.0	643.	-2.0	2.4	20.1
-3.0	-7.5	655.	-2.5	2.0	20.9
-3.3	-8.0	668.	-3.0	1.7	21.8
-3.7	-8.5	680.	-3.5	1.3	22.6
-4.0	-9.0	692.	-4.0	1.0	23.5
-4.4	-9.5	704.	-4.5	0.6	24.3
-4.7	-10.0	715.	-5.0	0.3	25.1

ALL DISTANCES ARE IN FEET

TABLE INCLUDES A 1.0 FOOT STAKING AND CONSTRUCTION TOLERANCE IN ADDITION TO THE BASIC CLEARANCES
TABLE INCLUDES A 1.0 FOOT UPLIFT FACTOR TOLERANCE

THIS TABLE MAY BE USED FOR ANY PHASE CONDUCTOR WHOSE MAXIMUM TEMPERATURE IS 120 DEGREES F OR LESS, AND WHOSE 60 DEGREE F FINAL SAG IN A 525. FOOT SPAN IS LESS THAN OR EQUAL TO 6.4 FEET

STAKING TABLE

TEMP F	0	10	20	30	40	50	60	70	80	90	100
HORIZONTAL TENSION	1517	1453	1389	1326	1262	1198	1135	1075	1015	955	902
SPAN FT.	STRINGING SAG-INCHES										
450	29.	30.	32.	33.	35.	37.	39.	41.	44.	46.	49.
460	30.	32.	33.	35.	37.	39.	41.	43.	46.	48.	52.
470	32.	33.	35.	36.	38.	40.	42.	45.	48.	50.	54.
480	33.	35.	36.	38.	40.	42.	44.	47.	50.	53.	56.
490	35.	36.	38.	39.	42.	44.	46.	49.	52.	55.	58.
500	36.	38.	39.	41.	43.	46.	48.	51.	54.	57.	61.
510	37.	39.	41.	43.	45.	48.	50.	53.	56.	59.	63.
520	39.	41.	43.	44.	47.	49.	52.	55.	58.	62.	66.
525 RS	40.	42.	43.	45.	48.	50.	53.	56.	60.	63.	67.
530	40.	42.	44.	46.	49.	51.	54.	57.	61.	64.	68.
540	42.	44.	46.	48.	51.	53.	56.	60.	63.	67.	71.
550	43.	46.	48.	50.	53.	55.	58.	62.	65.	69.	74.
560	45.	47.	49.	52.	54.	57.	60.	64.	68.	72.	76.
570	47.	49.	51.	53.	56.	59.	62.	66.	70.	74.	79.
580	48.	51.	53.	55.	58.	62.	65.	69.	73.	77.	82.
590	50.	52.	55.	57.	60.	64.	67.	71.	75.	79.	85.
600	52.	54.	57.	59.	63.	66.	69.	74.	78.	82.	88.
610	53.	56.	59.	61.	65.	68.	71.	76.	80.	85.	91.
620	55.	58.	61.	63.	67.	70.	74.	78.	83.	88.	94.
630	57.	60.	63.	65.	69.	73.	76.	81.	86.	91.	97.
640	59.	62.	65.	67.	71.	75.	79.	84.	89.	94.	100.
650	61.	64.	67.	69.	73.	77.	81.	86.	91.	96.	103.
660	63.	66.	69.	72.	76.	80.	84.	89.	94.	99.	106.
670	65.	68.	71.	74.	78.	82.	86.	92.	97.	103.	109.
680	66.	70.	73.	76.	80.	85.	89.	94.	100.	106.	113.
690	68.	72.	75.	78.	83.	87.	91.	97.	103.	109.	116.
700	70.	74.	77.	81.	85.	90.	94.	100.	106.	112.	119.

INITIAL STRINGING SAGS AND TENSIONS

DESIGN POINTS TEMP,F	ICE,IN.	WIND,PSF	FINAL SAG, FT.	FINAL TENSION, LB.	INITIAL SAG, FT.	INITIAL TENSION, LB.
CREEP IS NOT A FACTOR						
15.0	1/4	4	10.78	2108.	10.78	2108.
32.0	1/4		8.40	1425.	7.45	1607.
60.0		4	7.34	925.	5.55	1223.
60.0		6	8.10	1049.	6.49	1309.
-20.0			3.55	1411.	3.05	1642.
0.0			4.09	1224.	3.30	1517.
15.0			4.57	(1095.)	3.52	1422.
30.0			5.12	978.	3.78	1326.
60.0			6.38	785.	4.41	1135.
90.0			7.76	646.	5.25	955.
120.0			9.15	548.	6.29	796.
140.0			9.68	518.	7.08	708.
167.0			10.22	491.	8.21	610.
200.0			10.88	461.	9.62	521.
212.0			11.12	451.	10.13	495.

RULING SPAN SAGS AND TENSIONS

CONDUCTOR 4/0 (6/1) ACSR **DESIGN RULING SPAN** 325 **FT.** **DESIGN TENSION** 3125 **LBS.**

RECOMMENDED FOR USE WITH RULING SPANS FROM 300 **FT. TO** 425 **FT.** MEDIUM **LOADING DISTRICT**

	PHASE	NEUTRAL
CONDUCTOR DESC.	4/0 (6/1) ACSR	4/0 (6/1) ACSR
MAX. OPERATING TEMP.	120. DEGREES F	120.DEGREES F
BASIC GROUND CLEAR.	20.0 FEET	18.0 FEET
DESIGN TENSION	2882. LBS (34.5 %)	2882. LBS (34.5 %)

325. FOOT RULING SPAN MEDIUM LOADING DISTRICT

FOR USE WITH A1,B1,AND C1 TYPE ASSEMBLIES

35.0 FOOT POLES QUARTER POINT OF SPAN	35.0 FOOT POLES CENTER OF SPAN	SPAN LENGTH	40.0 FOOT POLES CENTER OF SPAN	40.0 FOOT POLES QUARTER POINT OF SPAN	UPLIFT FACTOR
5.4	5.0	234.	10.0	10.4	2.3
5.0	4.5	262.	9.5	10.0	3.2
4.7	4.0	282.	9.0	9.7	3.8
4.4	3.5	301.	8.5	9.4	4.5
4.0	3.0	320.	8.0	9.0	5.2
3.7	2.5	337.	7.5	8.7	5.9
3.4	2.0	355.	7.0	8.4	6.6
3.1	1.5	371.	6.5	8.1	7.4
2.7	1.0	388.	6.0	7.7	8.1
2.4	0.5	403.	5.5	7.4	8.9
2.0	LEVEL 0.0	419.	5.0	7.0	9.6
1.7	-0.5	434.	4.5	6.7	10.4
1.4	-1.0	448.	4.0	6.4	11.2
1.0	-1.5	463.	3.5	6.0	12.0
0.7	-2.0	477.	3.0	5.7	12.8
0.4	-2.5	490.	2.5	5.4	13.6
0.0	-3.0	504.	2.0	5.0	14.4
-0.3	-3.5	517.	1.5	4.7	15.2
-0.7	-4.0	530.	1.0	4.3	16.0
-1.0	-4.5	542.	0.5	4.0	16.8
-1.4	-5.0	555.	LEVEL 0.0	3.6	17.7
-1.7	-5.5	567.	-0.5	3.3	18.5
-2.1	-6.0	579.	-1.0	2.9	19.3
-2.4	-6.5	591.	-1.5	2.6	20.2
-2.7	-7.0	603.	-2.0	2.3	21.0
-3.1	-7.5	614.	-2.5	1.9	21.9
-3.4	-8.0	626.	-3.0	1.6	22.7
-3.8	-8.5	637.	-3.5	1.2	23.6
-4.1	-9.0	648.	-4.0	0.9	24.4
-4.5	-9.5	659.	-4.5	0.5	25.3
-4.8	-10.0	669.	-5.0	0.2	26.2

ALL DISTANCES ARE IN FEET

TABLE INCLUDES A 1.0 FOOT STAKING AND CONSTRUCTION TOLERANCE IN ADDITION TO THE BASIC CLEARANCES
TABLE INCLUDES A 1.0 FOOT UPLIFT FACTOR TOLERANCE

THIS TABLE MAY BE USED FOR ANY PHASE CONDUCTOR WHOSE MAXIMUM TEMPERATURE IS 120 DEGREES F OR LESS, AND WHOSE 60 DEGREE F FINAL SAG IN A 325. FOOT SPAN IS LESS THAN OR EQUAL TO 2.9 FEET

STAKING TABLE

TEMP F	0	10	20	30	40	50	60	70	80	90	100
HORIZONTAL TENSION	2608	2467	2326	2186	2045	1905	1765	1636	1507	1378	1274
SPAN FT.	STRINGING SAG-INCHES										
200	7.	7.	8.	8.	9.	9.	10.	11.	12.	13.	14.
210	7.	8.	8.	9.	10.	10.	11.	12.	13.	14.	15.
220	8.	9.	9.	10.	10.	11.	12.	13.	14.	15.	17.
230	9.	9.	10.	11.	11.	12.	13.	14.	16.	17.	18.
240	10.	10.	11.	12.	12.	13.	14.	16.	17.	18.	20.
250	10.	11.	12.	12.	13.	14.	15.	17.	18.	20.	22.
260	11.	12.	13.	14.	15.	16.	17.	18.	20.	21.	24.
270	12.	13.	14.	15.	16.	17.	18.	20.	21.	23.	25.
280	13.	14.	15.	16.	17.	18.	19.	21.	23.	25.	27.
290	14.	15.	16.	17.	18.	19.	21.	23.	25.	27.	29.
300	15.	16.	17.	18.	19.	21.	22.	24.	26.	29.	31.
310	16.	17.	18.	19.	21.	22.	24.	26.	28.	30.	33.
320	17.	18.	19.	20.	22.	24.	25.	28.	30.	32.	36.
325 RS	18.	19.	20.	21.	23.	24.	26.	29.	31.	33.	37.
330	18.	19.	21.	22.	23.	25.	27.	29.	32.	35.	38.
340	19.	21.	22.	23.	25.	27.	29.	31.	34.	37.	40.
350	21.	22.	23.	24.	26.	28.	30.	33.	36.	39.	43.
360	22.	23.	24.	26.	28.	30.	32.	35.	38.	41.	45.
370	23.	24.	26.	27.	30.	32.	34.	37.	40.	43.	48.
380	24.	26.	27.	29.	31.	33.	36.	39.	42.	46.	50.
390	25.	27.	29.	30.	33.	35.	38.	41.	45.	48.	53.
400	27.	29.	30.	32.	35.	37.	40.	43.	47.	51.	56.
410	28.	30.	32.	34.	36.	39.	42.	45.	49.	53.	58.
420	30.	31.	33.	35.	38.	41.	44.	48.	52.	56.	61.
430	31.	33.	35.	37.	40.	43.	46.	50.	54.	59.	64.

INITIAL STRINGING SAGS AND TENSIONS

DESIGN POINTS
CREEP IS A FACTOR

TEMP,F	ICE,IN.	WIND,PSF	FINAL SAG, FT.	FINAL TENSION, LB.	INITIAL SAG, FT.	INITIAL TENSION, LB.
15.0	1/4	4	4.01	2795.	3.89	2882.
32.0	1/4		3.37	2135.	3.00	2392.
60.0		4	3.20	1428.	2.50	1829.
60.0		6	3.49	1533.	2.81	1900.
-20.0			1.37	2814.	1.33	2880.
0.0			1.61	2391.	1.47	2608.
15.0			1.84	(2088.)	1.60	2398.
30.0			2.13	1804.	1.76	2186.
60.0			2.90	1325.	2.18	1765.
90.0			3.87	994.	2.79	1378.
120.0			4.88	789.	3.61	1066.
140.0			5.27	730.	4.22	912.
167.0			5.66	680.	5.06	760.
200.0			6.14	627.	5.98	644.
212.0			6.32	609.	6.15	626.

RULING SPAN SAGS AND TENSIONS

CONDUCTOR 4/0 (6/1) ACSR DESIGN RULING SPAN 425 FT. DESIGN TENSION 3325 LBS.

RECOMMENDED FOR USE WITH RULING SPANS FROM 400 FT. TO 525 FT. MEDIUM LOADING DISTRICT

	PHASE	NEUTRAL
CONDUCTOR DESC.	4/0 (6/1) ACSR	4/0 (6/1) ACSR
MAX. OPERATING TEMP.	120. DEGREES F	120. DEGREES F
BASIC GROUND CLEAR.	20.0 FEET	18.0 FEET
DESIGN TENSION	3108. LBS (37.2 %)	3108. LBS (37.2 %)

425. FOOT RULING SPAN MEDIUM LOADING DISTRICT

FOR USE WITH A1,B1,AND C1 TYPE ASSEMBLIES

35.0 FOOT POLES QUARTER POINT OF SPAN	35.0 FOOT POLES CENTER OF SPAN	SPAN LENGTH	40.0 FOOT POLES CENTER OF SPAN	40.0 FOOT POLES QUARTER POINT OF SPAN	UPLIFT FACTOR
5.4	5.0	242.	10.0	10.4	2.5
5.0	4.5	267.	9.5	10.0	3.3
4.7	4.0	288.	9.0	9.7	4.0
4.4	3.5	308.	8.5	9.4	4.7
4.1	3.0	327.	8.0	9.1	5.4
3.7	2.5	345.	7.5	8.7	6.1
3.4	2.0	363.	7.0	8.4	6.9
3.1	1.5	380.	6.5	8.1	7.7
2.7	1.0	397.	6.0	7.7	8.4
2.4	0.5	413.	5.5	7.4	9.2
2.1	LEVEL 0.0	429.	5.0	7.1	10.0
1.7	-0.5	444.	4.5	6.7	10.8
1.4	-1.0	459.	4.0	6.4	11.7
1.1	-1.5	474.	3.5	6.1	12.5
0.7	-2.0	488.	3.0	5.7	13.3
0.4	-2.5	503.	2.5	5.4	14.2
0.0	-3.0	516.	2.0	5.0	15.0
-0.3	-3.5	530.	1.5	4.7	15.9
-0.6	-4.0	543.	1.0	4.4	16.7
-1.0	-4.5	556.	0.5	4.0	17.6
-1.3	-5.0	569.	LEVEL 0.0	3.7	18.4
-1.7	-5.5	582.	-0.5	3.3	19.3
-2.0	-6.0	594.	-1.0	3.0	20.2
-2.4	-6.5	607.	-1.5	2.6	21.1
-2.7	-7.0	619.	-2.0	2.3	22.0
-3.0	-7.5	631.	-2.5	2.0	22.9
-3.4	-8.0	642.	-3.0	1.6	23.8
-3.7	-8.5	654.	-3.5	1.3	24.7
-4.1	-9.0	665.	-4.0	0.9	25.6
-4.4	-9.5	677.	-4.5	0.6	26.5
-4.8	-10.0	688.	-5.0	0.2	27.4

ALL DISTANCES ARE IN FEET

TABLE INCLUDES A 1.0 FOOT STAKING AND CONSTRUCTION TOLERANCE IN ADDITION TO THE BASIC CLEARANCES
TABLE INCLUDES A 1.0 FOOT UPLIFT FACTOR TOLERANCE

THIS TABLE MAY BE USED FOR ANY PHASE CONDUCTOR WHOSE MAXIMUM TEMPERATURE IS 120 DEGREES F OR LESS, AND WHOSE 60 DEGREE F FINAL SAG IN A 425. FOOT SPAN IS LESS THAN OR EQUAL TO 4.6 FEET

STAKING TABLE

TEMP F	0	10	20	30	40	50	60	70	80	90	100
HORIZONTAL TENSION	2626	2493	2360	2227	2097	1968	1838	1723	1607	1491	1398
SPAN FT.				STRINGING SAG-INCHES							
320	17.	18.	19.	20.	21.	23.	24.	26.	28.	30.	32.
330	18.	19.	20.	21.	23.	24.	26.	28.	30.	32.	34.
340	19.	20.	22.	23.	24.	26.	27.	30.	32.	34.	36.
350	20.	22.	23.	24.	26.	27.	29.	31.	34.	36.	39.
360	22.	23.	24.	25.	27.	29.	31.	33.	36.	38.	41.
370	23.	24.	25.	27.	29.	31.	33.	35.	38.	40.	43.
380	24.	25.	27.	28.	30.	32.	34.	37.	40.	42.	46.
390	25.	27.	28.	30.	32.	34.	36.	39.	42.	45.	48.
400	27.	28.	30.	31.	34.	36.	38.	41.	44.	47.	50.
410	28.	30.	31.	33.	35.	38.	40.	43.	46.	49.	53.
420	29.	31.	33.	35.	37.	39.	42.	45.	48.	52.	56.
425 RS	30.	32.	34.	35.	38.	40.	43.	46.	50.	53.	57.
430	31.	33.	34.	36.	39.	41.	44.	47.	51.	54.	58.
440	32.	34.	36.	38.	41.	43.	46.	50.	53.	57.	61.
450	34.	36.	38.	40.	43.	45.	48.	52.	56.	59.	64.
460	35.	37.	39.	41.	44.	47.	50.	54.	58.	62.	67.
470	37.	39.	41.	43.	46.	49.	52.	57.	61.	65.	70.
480	38.	41.	43.	45.	48.	52.	55.	59.	63.	67.	73.
490	40.	42.	45.	47.	50.	54.	57.	61.	66.	70.	76.
500	42.	44.	47.	49.	52.	56.	59.	64.	69.	73.	79.
510	43.	46.	48.	51.	55.	58.	62.	67.	71.	76.	82.
520	45.	48.	50.	53.	57.	60.	64.	69.	74.	79.	85.
530	47.	50.	52.	55.	59.	63.	67.	72.	77.	82.	89.
540	48.	51.	54.	57.	61.	65.	69.	75.	80.	85.	92.
550	50.	53.	56.	59.	64.	68.	72.	77.	83.	89.	95.
560	52.	55.	58.	62.	66.	70.	74.	80.	86.	92.	99.
570	54.	57.	60.	64.	68.	73.	77.	83.	89.	95.	102.
580	56.	59.	63.	66.	71.	75.	80.	86.	92.	99.	106.
590	58.	61.	65.	68.	73.	78.	83.	89.	96.	102.	110.
600	60.	63.	67.	71.	76.	81.	86.	92.	99.	105.	114.

INITIAL STRINGING SAGS AND TENSIONS

DESIGN POINTS TEMP,F	ICE,IN.	WIND,PSF	FINAL SAG, FT.	FINAL TENSION, LB.	INITIAL SAG, FT.	INITIAL TENSION, LB.
CREEP IS A FACTOR						
15.0	1/4	4	6.29	3051.	6.18	3108.
32.0	1/4		5.34	2300.	4.84	2538.
60.0		4	5.05	1551.	4.06	1929.
60.0		6	5.44	1683.	4.52	2025.
-20.0			2.38	2761.	2.28	2889.
0.0			2.78	2365.	2.50	2626.
15.0			3.15	(2088.)	2.71	2426.
30.0			3.58	1835.	2.95	2227.
60.0			4.63	1420.	3.58	1839.
90.0			5.82	1130.	4.41	1492.
120.0			7.03	937.	5.42	1213.
140.0			7.76	849.	6.16	1069.
167.0			8.23	801.	7.16	920.
200.0			8.80	748.	8.35	789.
212.0			9.01	731.	8.76	752.

RULING SPAN SAGS AND TENSIONS

CONDUCTOR 4/0 (6/1) ACSR DESIGN RULING SPAN 525 FT. DESIGN TENSION 3325 LBS.

RECOMMENDED FOR USE WITH RULING SPANS FROM 500 FT. TO 625 FT. MEDIUM LOADING DISTRICT

	PHASE	NEUTRAL
CONDUCTOR DESC.	4/0 (6/1) ACSR	4/0 (6/1) ACSR
MAX. OPERATING TEMP.	120. DEGREES F	120. DEGREES F
BASIC GROUND CLEAR.	20.0 FEET	18.0 FEET
DESIGN TENSION	3317 LBS (39.7 %)	3317 LBS (39.7 %)

525. FOOT RULING SPAN MEDIUM LOADING DISTRICT

FOR USE WITH A1,B1,AND C1 TYPE ASSEMBLIES

35.0 FOOT POLES QUARTER POINT OF SPAN	35.0 FOOT POLES CENTER OF SPAN	SPAN LENGTH	40.0 FOOT POLES CENTER OF SPAN	40.0 FOOT POLES QUARTER POINT OF SPAN	UPLIFT FACTOR
5.4	5.0	249.	10.0	10.4	2.7
5.1	4.5	271.	9.5	10.1	3.4
4.7	4.0	293.	9.0	9.7	4.1
4.4	3.5	313.	8.5	9.4	4.8
4.1	3.0	332.	8.0	9.1	5.6
3.8	2.5	351.	7.5	8.8	6.4
3.4	2.0	369.	7.0	8.4	7.1
3.1	1.5	387.	6.5	8.1	7.9
2.8	1.0	404.	6.0	7.8	8.7
2.4	0.5	421.	5.5	7.4	9.6
2.1	LEVEL 0.0	437.	5.0	7.1	10.4
1.8	-0.5	453.	4.5	6.8	11.2
1.4	-1.0	468.	4.0	6.4	12.1
1.1	-1.5	483.	3.5	6.1	12.9
0.7	-2.0	498.	3.0	5.7	13.8
0.4	-2.5	513.	2.5	5.4	14.7
0.1	-3.0	527.	2.0	5.1	15.6
-0.3	-3.5	541.	1.5	4.7	16.5
-0.6	-4.0	555.	1.0	4.4	17.3
-1.0	-4.5	568.	0.5	4.0	18.2
-1.3	-5.0	581.	LEVEL 0.0	3.7	19.2
-1.6	-5.5	594.	-0.5	3.4	20.1
-2.0	-6.0	607.	-1.0	3.0	21.0
-2.3	-6.5	620.	-1.5	2.7	21.9
-2.7	-7.0	632.	-2.0	2.3	22.8
-3.0	-7.5	644.	-2.5	2.0	23.8
-3.4	-8.0	656.	-3.0	1.6	24.7
-3.7	-8.5	668.	-3.5	1.3	25.6
-4.1	-9.0	680.	-4.0	0.9	26.6
-4.4	-9.5	691.	-4.5	0.6	27.5
-4.7	-10.0	703.	-5.0	0.3	28.5

ALL DISTANCES ARE IN FEET

TABLE INCLUDES A 1.0 FOOT STAKING AND CONSTRUCTION TOLERANCE IN ADDITION TO THE BASIC CLEARANCES
TABLE INCLUDES A 1.0 FOOT UPLIFT FACTOR TOLERANCE

THIS TABLE MAY BE USED FOR ANY PHASE CONDUCTOR WHOSE MAXIMUM TEMPERATURE IS 120 DEGREES F OR LESS, AND WHOSE 60 DEGREE F FINAL SAG IN A 525. FOOT SPAN IS LESS THAN OR EQUAL TO 6.7 FEET

STAKING TABLE

TEMP F	0	10	20	30	40	50	60	70	80	90	100
HORIZONTAL TENSION	2630	2505	2380	2254	2136	2017	1898	1794	1690	1586	1502
SPAN FT.	STRINGING SAG-INCHES										
450	34.	35.	37.	39.	42.	44.	47.	50.	53.	56.	59.
460	35.	37.	39.	41.	44.	46.	49.	52.	55.	58.	62.
470	37.	39.	41.	43.	45.	48.	51.	54.	57.	61.	65.
480	38.	40.	43.	45.	47.	50.	53.	56.	60.	63.	67.
490	40.	42.	44.	47.	49.	52.	55.	59.	62.	66.	70.
500	42.	44.	46.	48.	51.	54.	58.	61.	65.	69.	73.
510	43.	46.	48.	50.	54.	57.	60.	64.	68.	72.	76.
520	45.	47.	50.	52.	56.	59.	62.	66.	70.	74.	79.
525 RS	46.	48.	51.	53.	57.	60.	63.	68.	72.	76.	81.
530	47.	49.	52.	54.	58.	61.	65.	69.	73.	77.	82.
540	48.	51.	54.	56.	60.	64.	67.	71.	76.	80.	85.
550	50.	53.	56.	59.	62.	66.	70.	74.	79.	83.	89.
560	52.	55.	58.	61.	65.	68.	72.	77.	82.	86.	92.
570	54.	57.	60.	63.	67.	71.	75.	80.	85.	89.	95.
580	56.	59.	62.	65.	69.	73.	77.	82.	88.	93.	98.
590	58.	61.	64.	67.	72.	76.	80.	85.	91.	96.	102.
600	60.	63.	66.	70.	74.	78.	83.	88.	94.	99.	105.
610	62.	65.	69.	72.	77.	81.	86.	91.	97.	102.	109.
620	64.	67.	71.	74.	79.	84.	88.	94.	100.	106.	113.
630	66.	70.	73.	77.	82.	87.	91.	97.	103.	109.	116.
640	68.	72.	76.	79.	84.	89.	94.	100.	107.	113.	120.
650	70.	74.	78.	82.	87.	92.	97.	104.	110.	116.	124.
660	72.	76.	80.	84.	90.	95.	100.	107.	113.	120.	128.
670	75.	79.	83.	87.	92.	98.	103.	110.	117.	124.	131.
680	77.	81.	85.	90.	95.	101.	106.	113.	120.	127.	135.
690	79.	83.	88.	92.	98.	104.	110.	117.	124.	131.	139.
700	81.	86.	90.	95.	101.	107.	113.	120.	128.	135.	143.

INITIAL STRINGING SAGS AND TENSIONS

DESIGN POINTS TEMP,F	ICE,IN.	WIND,PSF	FINAL SAG, FT.	FINAL TENSION, LB.	INITIAL SAG, FT.	INITIAL TENSION, LB.
CREEP IS A FACTOR						
15.0	1/4	4	8.91	3287.	8.83	3317.
32.0	1/4		7.66	2450.	7.03	2670.
60.0		4	7.20	1658.	5.93	2014.
60.0		6	7.70	1815.	6.54	2135.
-20.0			3.71	2701.	3.48	2882.
0.0			4.29	2337.	3.81	2631.
15.0			4.81	(2088.)	4.11	2441.
30.0			5.38	1865.	4.45	2255.
60.0			6.68	1503.	5.28	1899.
90.0			8.07	1244.	6.33	1587.
120.0			9.45	1063.	7.52	1335.
140.0			10.33	973.	8.36	1201.
167.0			11.09	907.	9.51	1057.
200.0			11.75	856.	10.88	924.
212.0			11.99	839.	11.36	885.

RULING SPAN SAGS AND TENSIONS

CONDUCTOR NO. 4 (7/1) ACSR **DESIGN RULING SPAN** 325 **FT. DESIGN TENSION** 975 **LBS.**

RECOMMENDED FOR USE WITH RULING SPANS FROM 300 **FT. TO** 425 **FT.** LIGHT **LOADING DISTRICT**

STAKING TABLE

	PHASE	NEUTRAL
CONDUCTOR DESC.	NO. 4(7/1) ACSR	NO. 4(7/1) ACSR
MAX. OPERATING TEMP.	120. DEGREES F	120.DEGREES F
BASIC GROUND CLEAR.	20.0 FEET	18.0 FEET
DESIGN TENSION	851. LBS (36.1 %)	851. LBS (36.1 %)

325. FOOT RULING SPAN LIGHT LOADING DISTRICT

FOR USE WITH A1,B1,AND C1 TYPE ASSEMBLIES

35.0 FOOT POLES QUARTER POINT OF SPAN	35.0 FOOT POLES CENTER OF SPAN	SPAN LENGTH	40.0 FOOT POLES CENTER OF SPAN	40.0 FOOT POLES QUARTER POINT OF SPAN	UPLIFT FACTOR
5.4	5.0	286.	10.0	10.4	2.8
5.0	4.5	330.	9.5	10.0	4.1
4.7	4.0	361.	9.0	9.7	5.1
4.3	3.5	382.	8.5	9.3	5.8
4.0	3.0	402.	8.0	9.0	6.5
3.7	2.5	422.	7.5	8.7	7.3
3.4	2.0	442.	7.0	8.4	8.1
3.0	1.5	461.	6.5	8.0	8.9
2.7	1.0	479.	6.0	7.7	9.7
2.4	0.5	497.	5.5	7.4	10.5
2.0	LEVEL 0.0	514.	5.0	7.0	11.3
1.7	-0.5	531.	4.5	6.7	12.2
1.4	-1.0	548.	4.0	6.4	13.0
1.0	-1.5	565.	3.5	6.0	13.8
0.7	-2.0	581.	3.0	5.7	14.7
0.4	-2.5	596.	2.5	5.4	15.6
0.0	-3.0	612.	2.0	5.0	16.4
-0.3	-3.5	627.	1.5	4.7	17.3
-0.6	-4.0	642.	1.0	4.4	18.2
-1.0	-4.5	657.	0.5	4.0	19.1
-1.3	-5.0	672.	LEVEL 0.0	3.7	20.0
-1.7	-5.5	686.	-0.5	3.3	20.9
-2.0	-6.0	700.	-1.0	3.0	21.8
-2.3	-6.5	714.	-1.5	2.7	22.7
-2.7	-7.0	728.	-2.0	2.3	23.7
-3.0	-7.5	741.	-2.5	2.0	24.6
-3.4	-8.0	754.	-3.0	1.6	25.5
-3.7	-8.5	768.	-3.5	1.3	26.4
-4.0	-9.0	781.	-4.0	1.0	27.4
-4.4	-9.5	794.	-4.5	0.6	28.3
-4.7	-10.0	806.	-5.0	0.3	29.3

ALL DISTANCES ARE IN FEET

TABLE INCLUDES A 1.0 FOOT STAKING AND CONSTRUCTION TOLERANCE IN ADDITION TO THE BASIC CLEARANCES
TABLE INCLUDES A 1.0 FOOT UPLIFT FACTOR TOLERANCE

THIS TABLE MAY BE USED FOR ANY PHASE CONDUCTOR WHOSE MAXIMUM TEMPERATURE IS 120 DEGREES F OR LESS, AND WHOSE 60 DEGREE F FINAL SAG IN A 325. FOOT SPAN IS LESS THAN OR EQUAL TO 1.9 FEET

INITIAL STRINGING SAGS AND TENSIONS

STRINGING SAG-INCHES

TEMP F	0	10	20	30	40	50	60	70	80	90	100
HORIZONTAL TENSION	816	783	751	718	682	647	611	574	536	499	462
SPAN FT.											
200	5.	5.	5.	6.	6.	6.	7.	7.	8.	8.	9.
210	5.	6.	6.	6.	7.	7.	7.	8.	8.	9.	10.
220	6.	6.	7.	7.	7.	8.	8.	9.	9.	10.	11.
230	7.	7.	7.	7.	8.	8.	9.	9.	10.	11.	12.
240	7.	7.	8.	8.	9.	9.	9.	10.	11.	12.	13.
250	8.	8.	8.	9.	9.	10.	10.	11.	12.	13.	14.
260	8.	9.	9.	9.	10.	11.	11.	12.	13.	14.	15.
270	9.	9.	10.	10.	11.	11.	12.	13.	14.	15.	16.
280	10.	10.	11.	11.	12.	12.	13.	14.	15.	16.	17.
290	10.	11.	11.	12.	12.	13.	14.	15.	16.	17.	19.
300	11.	12.	12.	13.	13.	14.	15.	16.	17.	18.	20.
310	12.	12.	13.	13.	14.	15.	16.	17.	18.	19.	21.
320	13.	13.	14.	14.	15.	16.	17.	18.	19.	21.	23.
325 RS	13.	14.	14.	15.	16.	17.	17.	19.	20.	21.	23.
330	13.	14.	15.	15.	16.	17.	18.	19.	21.	22.	24.
340	14.	15.	16.	16.	17.	18.	19.	20.	22.	23.	26.
350	15.	16.	16.	17.	18.	19.	20.	22.	23.	25.	27.
360	16.	17.	17.	18.	19.	20.	21.	23.	25.	26.	29.
370	17.	18.	18.	19.	20.	21.	23.	24.	26.	28.	30.
380	18.	19.	19.	20.	21.	23.	24.	26.	27.	29.	32.
390	19.	20.	20.	21.	23.	24.	25.	27.	29.	31.	34.
400	20.	21.	22.	22.	24.	25.	26.	28.	30.	32.	35.
410	21.	22.	23.	24.	25.	26.	28.	30.	32.	34.	37.
420	22.	23.	24.	25.	26.	28.	29.	31.	33.	36.	39.
430	23.	24.	25.	26.	27.	29.	30.	33.	35.	37.	41.

RULING SPAN SAGS AND TENSIONS

DESIGN POINTS

CREEP IS A FACTOR

TEMP,F	ICE,IN.	WIND,PSF	FINAL SAG, FT.	FINAL TENSION, LB.	INITIAL SAG, FT.	INITIAL TENSION, LB.
30.0		9	4.23	795.	3.95	851.
60.0		4	2.81	511.	2.24	642.
60.0		6	3.41	561.	2.84	674.
0.0			1.21	732.	1.08	816.
30.0			1.50	(590.)	1.23	718.
60.0			1.94	457.	1.45	611.
90.0			2.58	343.	1.77	499.
120.0			3.44	257.	2.29	387.
140.0			3.96	224.	2.77	320.
167.0			4.37	203.	3.58	248.
200.0			4.89	181.	4.55	195.
212.0			5.08	174.	4.74	187.

CONDUCTOR NO. 4 (7/1) ACSR **DESIGN RULING SPAN** 425 **FT.** **DESIGN TENSION** 975 **LBS.**

RECOMMENDED FOR USE WITH RULING SPANS FROM 400 **FT. TO** 525 **FT.** LIGHT **LOADING DISTRICT**

	PHASE	NEUTRAL
CONDUCTOR DESC.	NO. 4(7/1) ACSR	NO. 4(7/1) ACSR
MAX. OPERATING TEMP.	120. DEGREES F	120.DEGREES F
BASIC GROUND CLEAR.	20.0 FEET	18.0 FEET
DESIGN TENSION	911. LBS (38.6 %)	911. LBS (38.6 %)

425. FOOT RULING SPAN LIGHT LOADING DISTRICT

FOR USE WITH A1,B1,AND C1 TYPE ASSEMBLIES

35.0 FOOT QUARTER POINT OF SPAN	POLES CENTER OF SPAN	SPAN LENGTH	40.0 FOOT CENTER OF SPAN	POLES QUARTER POINT OF SPAN	UPLIFT FACTOR
5.4	5.0	289.	10.0	10.4	2.9
5.0	4.5	334.	9.5	10.0	4.2
4.7	4.0	363.	9.0	9.7	5.2
4.3	3.5	385.	8.5	9.3	5.9
4.0	3.0	405.	8.0	9.0	6.7
3.7	2.5	425.	7.5	8.7	7.5
3.4	2.0	445.	7.0	8.4	8.2
3.0	1.5	464.	6.5	8.0	9.1
2.7	1.0	482.	6.0	7.7	9.9
2.4	0.5	501.	5.5	7.4	10.7
2.0	LEVEL 0.0	518.	5.0	7.0	11.5
1.7	-0.5	536.	4.5	6.7	12.4
1.4	-1.0	552.	4.0	6.4	13.3
1.0	-1.5	569.	3.5	6.0	14.1
0.7	-2.0	585.	3.0	5.7	15.0
0.4	-2.5	601.	2.5	5.4	15.9
0.0	-3.0	617.	2.0	5.0	16.8
-0.3	-3.5	632.	1.5	4.7	17.7
-0.6	-4.0	648.	1.0	4.4	18.6
-1.0	-4.5	663.	0.5	4.0	19.5
-1.3	-5.0	677.	LEVEL 0.0	3.7	20.4
-1.6	-5.5	692.	-0.5	3.4	21.4
-2.0	-6.0	706.	-1.0	3.0	22.3
-2.3	-6.5	720.	-1.5	2.7	23.2
-2.7	-7.0	734.	-2.0	2.3	24.2
-3.0	-7.5	748.	-2.5	2.0	25.1
-3.3	-8.0	761.	-3.0	1.7	26.1
-3.7	-8.5	774.	-3.5	1.3	27.0
-4.0	-9.0	788.	-4.0	1.0	28.0
-4.4	-9.5	801.	-4.5	0.6	28.9
-4.7	-10.0	813.	-5.0	0.3	29.9

ALL DISTANCES ARE IN FEET

TABLE INCLUDES A 1.0 FOOT STAKING AND CONSTRUCTION TOLERANCE IN ADDITION TO THE BASIC CLEARANCES
TABLE INCLUDES A 1.0 FOOT UPLIFT FACTOR TOLERANCE

THIS TABLE MAY BE USED FOR ANY PHASE CONDUCTOR WHOSE MAXIMUM TEMPERATURE IS 120 DEGREES F OR LESS, AND WHOSE 60 DEGREE F FINAL SAG IN A 425. FOOT SPAN IS LESS THAN OR EQUAL TO 3.2 FEET

STAKING TABLE

TEMP F	0	10	20	30	40	50	60	70	80	90	100
HORIZONTAL TENSION	814	782	750	718	684	650	616	581	545	510	476
SPAN FT.				STRINGING SAG-INCHES							
320	13.	13.	14.	14.	15.	16.	17.	18.	19.	20.	22.
330	13.	14.	15.	15.	16.	17.	18.	19.	20.	21.	23.
340	14.	15.	16.	16.	17.	18.	19.	20.	21.	23.	25.
350	15.	16.	16.	17.	18.	19.	20.	21.	23.	24.	26.
360	16.	17.	17.	18.	19.	20.	21.	23.	24.	26.	28.
370	17.	18.	18.	19.	20.	21.	22.	24.	25.	27.	29.
380	18.	19.	19.	20.	21.	22.	24.	25.	27.	28.	31.
390	19.	20.	20.	21.	22.	24.	25.	27.	28.	30.	32.
400	20.	21.	22.	22.	24.	25.	26.	28.	30.	32.	34.
410	21.	22.	23.	24.	25.	26.	27.	29.	31.	33.	36.
420	22.	23.	24.	25.	26.	27.	29.	31.	33.	35.	38.
425 RS	22.	23.	24.	25.	27.	28.	29.	32.	34.	36.	39.
430	23.	24.	25.	26.	27.	29.	30.	32.	34.	36.	39.
440	24.	25.	26.	27.	29.	30.	32.	34.	36.	38.	41.
450	25.	26.	27.	28.	30.	31.	33.	35.	38.	40.	43.
460	26.	27.	28.	30.	31.	33.	35.	37.	39.	42.	45.
470	27.	28.	30.	31.	33.	34.	36.	39.	41.	44.	47.
480	28.	30.	31.	32.	34.	36.	38.	40.	43.	45.	49.
490	30.	31.	32.	34.	35.	37.	39.	42.	45.	47.	51.
500	31.	32.	34.	35.	37.	39.	41.	44.	46.	49.	53.
510	32.	34.	35.	36.	38.	40.	42.	45.	48.	51.	55.
520	33.	35.	36.	38.	40.	42.	44.	47.	50.	53.	58.
530	35.	36.	38.	39.	41.	44.	46.	49.	52.	55.	60.
540	36.	38.	39.	41.	43.	45.	48.	51.	54.	57.	62.
550	37.	39.	41.	42.	45.	47.	49.	53.	56.	60.	65.
560	39.	40.	42.	44.	46.	49.	51.	55.	58.	62.	67.
570	40.	42.	44.	45.	48.	51.	53.	57.	60.	64.	69.
580	42.	43.	45.	47.	50.	52.	55.	59.	63.	66.	72.
590	43.	45.	47.	49.	51.	54.	57.	61.	65.	69.	74.
600	44.	46.	48.	50.	53.	56.	59.	63.	67.	71.	77.

INITIAL STRINGING SAGS AND TENSIONS

DESIGN POINTS

CREEP IS A FACTOR

TEMP,F	ICE,IN.	WIND,PSF	FINAL SAG, FT.	FINAL TENSION, LB.	INITIAL SAG, FT.	INITIAL TENSION, LB.
30.0		9	6.59	872.	6.31	911.
60.0		4	4.52	544.	3.71	663.
60.0		6	5.38	609.	4.62	708.
0.0			2.08	726.	1.86	814.
30.0			2.56	(590.)	2.11	718.
60.0			3.24	467.	2.46	616.
90.0			4.14	366.	2.97	510.
120.0			5.22	290.	3.70	409.
140.0			5.98	253.	4.33	349.
167.0			6.54	232.	5.32	285.
200.0			7.17	211.	6.61	229.
212.0			7.40	205.	6.98	217.

RULING SPAN SAGS AND TENSIONS

CONDUCTOR NO. 4 (7/1) ACSR DESIGN RULING SPAN 525 FT. DESIGN TENSION 975 LBS.

RECOMMENDED FOR USE WITH RULING SPANS FROM 500 FT. TO 625 FT. LIGHT LOADING DISTRICT

	PHASE	NEUTRAL
CONDUCTOR DESC.	NO. 4(7/1) ACSR	NO. 4(7/1) ACSR
MAX. OPERATING TEMP.	120. DEGREES F	120.DEGREES F
BASIC GROUND CLEAR.	20.0 FEET	18.0 FEET
DESIGN TENSION	969. LBS (41.1 %)	969. LBS (41.1 %)

525. FOOT RULING SPAN LIGHT LOADING DISTRICT

FOR USE WITH A1,B1,AND C1 TYPE ASSEMBLIES

35.0 FOOT POLES QUARTER POINT OF SPAN	35.0 FOOT POLES CENTER OF SPAN	SPAN LENGTH	40.0 FOOT POLES CENTER OF SPAN	40.0 FOOT POLES QUARTER POINT OF SPAN	UPLIFT FACTOR
5.4	5.0	293.	10.0	10.4	3.0
5.0	4.5	339.	9.5	10.0	4.3
4.7	4.0	366.	9.0	9.7	5.2
4.3	3.5	387.	8.5	9.3	6.0
4.0	3.0	408.	8.0	9.0	6.8
3.7	2.5	428.	7.5	8.7	7.6
3.4	2.0	448.	7.0	8.4	8.4
3.0	1.5	467.	6.5	8.0	9.2
2.7	1.0	486.	6.0	7.7	10.0
2.4	0.5	504.	5.5	7.4	10.9
2.1	LEVEL 0.0	522.	5.0	7.1	11.7
1.7	-0.5	540.	4.5	6.7	12.6
1.4	-1.0	557.	4.0	6.4	13.5
1.1	-1.5	574.	3.5	6.1	14.4
0.7	-2.0	590.	3.0	5.7	15.3
0.4	-2.5	606.	2.5	5.4	16.2
0.1	-3.0	622.	2.0	5.1	17.1
-0.3	-3.5	638.	1.5	4.7	18.0
-0.6	-4.0	653.	1.0	4.4	18.9
-1.0	-4.5	668.	0.5	4.0	19.9
-1.3	-5.0	683.	LEVEL 0.0	3.7	20.8
-1.6	-5.5	697.	-0.5	3.4	21.7
-2.0	-6.0	712.	-1.0	3.0	22.7
-2.3	-6.5	726.	-1.5	2.7	23.6
-2.6	-7.0	740.	-2.0	2.4	24.6
-3.0	-7.5	754.	-2.5	2.0	25.6
-3.3	-8.0	768.	-3.0	1.7	26.5
-3.7	-8.5	781.	-3.5	1.3	27.5
-4.0	-9.0	794.	-4.0	1.0	28.5
-4.4	-9.5	807.	-4.5	0.6	29.5
-4.7	-10.0	820.	-5.0	0.3	30.5

ALL DISTANCES ARE IN FEET

TABLE INCLUDES A 1.0 FOOT STAKING AND CONSTRUCTION TOLERANCE IN ADDITION TO THE BASIC CLEARANCES
TABLE INCLUDES A 1.0 FOOT UPLIFT FACTOR TOLERANCE

THIS TABLE MAY BE USED FOR ANY PHASE CONDUCTOR WHOSE MAXIMUM TEMPERATURE IS 120 DEGREES F OR LESS, AND WHOSE 60 DEGREE F FINAL SAG IN A 525. FOOT SPAN IS LESS THAN OR EQUAL TO 4.8 FEET

STAKING TABLE

TEMP F	0	10	20	30	40	50	60	70	80	90	100
HORIZONTAL TENSION	811	780	749	718	685	653	620	587	554	521	490
SPAN FT.	STRINGING SAG-INCHES										
420	22.	23.	24.	25.	26.	27.	29.	30.	32.	34.	36.
430	23.	24.	25.	26.	27.	29.	30.	32.	34.	36.	38.
440	24.	25.	26.	27.	29.	30.	31.	33.	35.	37.	40.
450	25.	26.	27.	28.	30.	31.	33.	35.	37.	39.	42.
460	26.	27.	28.	30.	31.	33.	34.	36.	39.	41.	44.
470	27.	29.	30.	31.	33.	34.	36.	38.	40.	43.	46.
480	29.	30.	31.	32.	34.	36.	37.	40.	42.	44.	48.
490	30.	31.	32.	34.	35.	37.	39.	41.	44.	46.	50.
500	31.	32.	34.	35.	37.	39.	41.	43.	46.	48.	52.
510	32.	34.	35.	36.	38.	40.	42.	45.	48.	50.	54.
520	34.	35.	36.	38.	40.	42.	44.	47.	49.	52.	56.
525 RS	34.	36.	37.	39.	41.	43.	45.	48.	50.	53.	57.
530	35.	36.	38.	39.	41.	43.	46.	48.	51.	54.	58.
540	36.	38.	39.	41.	43.	45.	47.	50.	53.	56.	60.
550	37.	39.	41.	42.	45.	47.	49.	52.	55.	58.	63.
560	39.	41.	42.	44.	46.	49.	51.	54.	57.	61.	65.
570	40.	42.	44.	45.	48.	50.	53.	56.	59.	63.	67.
580	42.	43.	45.	47.	50.	52.	55.	58.	61.	65.	70.
590	43.	45.	47.	49.	51.	54.	56.	60.	64.	67.	72.
600	45.	47.	48.	50.	53.	56.	58.	62.	66.	69.	74.
610	46.	48.	50.	52.	55.	58.	60.	64.	68.	72.	77.
620	48.	50.	52.	54.	57.	59.	62.	66.	70.	74.	79.
630	49.	51.	53.	56.	58.	61.	64.	68.	73.	77.	82.
640	51.	53.	55.	57.	60.	63.	66.	71.	75.	79.	85.
650	52.	55.	57.	59.	62.	65.	69.	73.	77.	82.	87.
660	54.	56.	59.	61.	64.	67.	71.	75.	80.	84.	90.
670	56.	58.	60.	63.	66.	69.	73.	77.	82.	87.	93.
680	57.	60.	62.	65.	68.	72.	75.	80.	84.	89.	96.
690	59.	62.	64.	67.	70.	74.	77.	82.	87.	92.	98.
700	61.	63.	66.	69.	72.	76.	79.	84.	90.	95.	101.

INITIAL STRINGING SAGS AND TENSIONS

DESIGN POINTS
CREEP IS A FACTOR

TEMP,F	ICE,IN.	WIND,PSF	FINAL SAG, FT.	FINAL TENSION, LB.	INITIAL SAG, FT.	INITIAL TENSION, LB.
30.0		9	9.28	945.	9.05	969.
60.0		4	6.53	574.	5.48	684.
60.0		6	7.64	654.	6.73	743.
0.0			3.22	718.	2.85	811.
30.0			3.91	(590.)	3.22	718.
60.0			4.83	478.	3.72	620.
90.0			5.97	387.	4.43	521.
120.0			7.25	319.	5.38	429.
140.0			8.12	285.	6.15	376.
167.0			8.97	258.	7.30	317.
200.0			9.70	238.	8.77	264.
212.0			9.97	232.	9.30	249.

RULING SPAN SAGS AND TENSIONS

CONDUCTOR NO. 2 (6/1) ACSR **DESIGN RULING SPAN** 325 **FT. DESIGN TENSION** 1250 **LBS.**

RECOMMENDED FOR USE WITH RULING SPANS FROM 300 **FT. TO** 425 **FT.** LIGHT **LOADING DISTRICT**

	PHASE	NEUTRAL
CONDUCTOR DESC.	NO. 2(6/1) ACSR	NO. 2(6/1) ACSR
MAX. OPERATING TEMP.	120. DEGREES F	120.DEGREES F
BASIC GROUND CLEAR.	20.0 FEET	18.0 FEET
DESIGN TENSION	1085. LBS (38.1 %)	1085. LBS (38.1 %)

325. FOOT RULING SPAN LIGHT LOADING DISTRICT

FOR USE WITH A1,B1,AND C1 TYPE ASSEMBLIES

35.0 FOOT POLES QUARTER POINT OF SPAN	35.0 FOOT POLES CENTER OF SPAN	SPAN LENGTH	40.0 FOOT POLES CENTER OF SPAN	40.0 FOOT POLES QUARTER POINT OF SPAN	UPLIFT FACTOR
5.4	5.0	264.	10.0	10.4	2.4
5.0	4.5	305.	9.5	10.0	3.5
4.6	4.0	341.	9.0	9.6	4.7
4.3	3.5	364.	8.5	9.3	5.5
4.0	3.0	384.	8.0	9.0	6.2
3.6	2.5	402.	7.5	8.6	6.9
3.3	2.0	420.	7.0	8.3	7.6
3.0	1.5	438.	6.5	8.0	8.4
2.6	1.0	455.	6.0	7.6	9.1
2.3	0.5	472.	5.5	7.3	9.9
2.0	LEVEL 0.0	488.	5.0	7.0	10.6
1.6	-0.5	504.	4.5	6.6	11.4
1.3	-1.0	520.	4.0	6.3	12.2
1.0	-1.5	535.	3.5	6.0	13.0
0.6	-2.0	550.	3.0	5.6	13.8
0.3	-2.5	565.	2.5	5.3	14.6
-0.1	-3.0	579.	2.0	4.9	15.4
-0.4	-3.5	593.	1.5	4.6	16.2
-0.7	-4.0	607.	1.0	4.3	17.0
-1.1	-4.5	621.	0.5	3.9	17.8
-1.4	-5.0	635.	LEVEL 0.0	3.6	18.7
-1.8	-5.5	648.	-0.5	3.2	19.5
-2.1	-6.0	661.	-1.0	2.9	20.3
-2.4	-6.5	674.	-1.5	2.6	21.2
-2.8	-7.0	687.	-2.0	2.2	22.0
-3.1	-7.5	699.	-2.5	1.9	22.9
-3.5	-8.0	712.	-3.0	1.5	23.7
-3.8	-8.5	724.	-3.5	1.2	24.6
-4.2	-9.0	736.	-4.0	0.8	25.5
-4.5	-9.5	748.	-4.5	0.5	26.3
-4.9	-10.0	760.	-5.0	0.1	27.2

ALL DISTANCES ARE IN FEET

TABLE INCLUDES A 1.0 FOOT STAKING AND CONSTRUCTION TOLERANCE IN ADDITION TO THE BASIC CLEARANCES
TABLE INCLUDES A 1.0 FOOT UPLIFT FACTOR TOLERANCE

THIS TABLE MAY BE USED FOR ANY PHASE CONDUCTOR WHOSE MAXIMUM TEMPERATURE IS 120 DEGREES F OR LESS, AND WHOSE 60 DEGREE F FINAL SAG IN A 325. FOOT SPAN IS LESS THAN OR EQUAL TO 2.3 FEET

STAKING TABLE

TEMP F	0	10	20	30	40	50	60	70	80	90	100
HORIZONTAL TENSION	1071	1026	980	935	886	838	789	738	688	637	588
SPAN FT.	STRINGING SAG-INCHES										
200	5.	5.	6.	6.	6.	7.	7.	7.	8.	9.	9.
210	6.	6.	6.	6.	7.	7.	8.	8.	9.	9.	10.
220	6.	6.	7.	7.	8.	8.	8.	9.	10.	10.	11.
230	7.	7.	7.	8.	8.	9.	9.	10.	11.	11.	13.
240	7.	8.	8.	8.	9.	9.	10.	11.	12.	12.	14.
250	8.	8.	9.	9.	10.	10.	11.	12.	13.	13.	15.
260	9.	9.	9.	10.	11.	11.	12.	13.	14.	15.	16.
270	9.	10.	10.	11.	11.	12.	13.	14.	15.	16.	17.
280	10.	11.	11.	11.	12.	13.	14.	15.	16.	17.	19.
290	11.	11.	12.	12.	13.	14.	15.	16.	17.	18.	20.
300	12.	12.	13.	13.	14.	15.	16.	17.	18.	19.	21.
310	12.	13.	13.	14.	15.	16.	17.	18.	19.	21.	23.
320	13.	14.	14.	15.	16.	17.	18.	19.	21.	22.	24.
325 RS	14.	14.	15.	15.	16.	17.	18.	20.	21.	23.	25.
330	14.	15.	15.	16.	17.	18.	19.	20.	22.	23.	26.
340	15.	15.	16.	17.	18.	19.	20.	22.	23.	25.	27.
350	16.	16.	17.	18.	19.	20.	21.	23.	25.	26.	29.
360	17.	17.	18.	19.	20.	21.	22.	24.	26.	28.	31.
370	18.	18.	19.	20.	21.	23.	24.	26.	28.	29.	32.
380	18.	19.	20.	21.	22.	24.	25.	27.	29.	31.	34.
390	19.	20.	21.	22.	24.	25.	26.	29.	31.	33.	36.
400	20.	21.	22.	23.	25.	26.	28.	30.	32.	34.	38.
410	21.	23.	24.	25.	26.	28.	29.	32.	34.	36.	40.
420	23.	24.	25.	26.	27.	29.	31.	33.	35.	38.	42.
430	24.	25.	26.	27.	29.	30.	32.	35.	37.	40.	44.

INITIAL STRINGING SAGS AND TENSIONS

DESIGN POINTS TEMP,F	ICE,IN.	WIND,PSF	FINAL SAG, FT.	FINAL TENSION, LB.	INITIAL SAG, FT.	INITIAL TENSION, LB.
CREEP IS A FACTOR						
30.0		9	4.15	968.	3.70	1085.
60.0		4	3.05	605.	2.23	825.
60.0		6	3.60	670.	2.79	863.
0.0			1.32	915.	1.13	1071.
30.0			1.69	(713.)	1.29	935.
60.0			2.27	531.	1.53	789.
90.0			3.10	388.	1.89	637.
120.0			4.08	296.	2.47	489.
140.0			4.34	278.	2.99	403.
167.0			4.71	256.	3.85	313.
200.0			5.18	233.	4.96	243.
212.0			5.36	225.	5.27	229.

RULING SPAN SAGS AND TENSIONS

CONDUCTOR NO. 2 (6/1) ACSR **DESIGN RULING SPAN** 425 **FT. DESIGN TENSION** 1250 **LBS.**

RECOMMENDED FOR USE WITH RULING SPANS FROM 400 **FT. TO** 525 **FT.** LIGHT **LOADING DISTRICT**

	PHASE	NEUTRAL
CONDUCTOR DESC.	NO. 2(6/1) ACSR	NO. 2(6/1) ACSR
MAX. OPERATING TEMP.	120. DEGREES F	120.DEGREES F
BASIC GROUND CLEAR.	20.0 FEET	18.0 FEET
DESIGN TENSION	1157. LBS (40.6 %)	1157. LBS (40.6 %)

425. FOOT RULING SPAN LIGHT LOADING DISTRICT

FOR USE WITH A1,B1,AND C1 TYPE ASSEMBLIES

35.0 FOOT POLES QUARTER POINT OF SPAN	35.0 FOOT POLES CENTER OF SPAN	SPAN LENGTH	40.0 FOOT POLES CENTER OF SPAN	40.0 FOOT POLES QUARTER POINT OF SPAN	UPLIFT FACTOR
5.4	5.0	269.	10.0	10.4	2.5
5.0	4.5	310.	9.5	10.0	3.7
4.6	4.0	347.	9.0	9.6	4.9
4.3	3.5	368.	8.5	9.3	5.6
4.0	3.0	388.	8.0	9.0	6.3
3.6	2.5	407.	7.5	8.6	7.1
3.3	2.0	425.	7.0	8.3	7.8
3.0	1.5	443.	6.5	8.0	8.6
2.7	1.0	460.	6.0	7.7	9.3
2.3	0.5	477.	5.5	7.3	10.1
2.0	LEVEL 0.0	494.	5.0	7.0	10.9
1.7	-0.5	510.	4.5	6.7	11.7
1.3	-1.0	526.	4.0	6.3	12.5
1.0	-1.5	541.	3.5	6.0	13.3
0.6	-2.0	557.	3.0	5.6	14.1
0.3	-2.5	572.	2.5	5.3	14.9
0.0	-3.0	586.	2.0	5.0	15.7
-0.4	-3.5	601.	1.5	4.6	16.6
-0.7	-4.0	615.	1.0	4.3	17.4
-1.1	-4.5	629.	0.5	3.9	18.3
-1.4	-5.0	643.	LEVEL 0.0	3.6	19.1
-1.7	-5.5	656.	-0.5	3.3	20.0
-2.1	-6.0	669.	-1.0	2.9	20.8
-2.4	-6.5	683.	-1.5	2.6	21.7
-2.8	-7.0	696.	-2.0	2.2	22.6
-3.1	-7.5	708.	-2.5	1.9	23.4
-3.4	-8.0	721.	-3.0	1.6	24.3
-3.8	-8.5	733.	-3.5	1.2	25.2
-4.1	-9.0	746.	-4.0	0.9	26.1
-4.5	-9.5	758.	-4.5	0.5	27.0
-4.8	-10.0	770.	-5.0	0.2	27.9

ALL DISTANCES ARE IN FEET

TABLE INCLUDES A 1.0 FOOT STAKING AND CONSTRUCTION TOLERANCE IN ADDITION TO THE BASIC CLEARANCES
TABLE INCLUDES A 1.0 FOOT UPLIFT FACTOR TOLERANCE

THIS TABLE MAY BE USED FOR ANY PHASE CONDUCTOR WHOSE MAXIMUM TEMPERATURE IS 120 DEGREES F OR LESS, AND WHOSE 60 DEGREE F FINAL SAG IN A 425. FOOT SPAN IS LESS THAN OR EQUAL TO 3.7 FEET

STAKING TABLE

TEMP F	0	10	20	30	40	50	60	70	80	90	100
HORIZONTAL TENSION	1071	1027	982	938	891	845	798	751	703	656	612
SPAN FT.	STRINGING SAG-INCHES										
320	13.	14.	14.	15.	16.	17.	18.	19.	20.	21.	23.
330	14.	15.	15.	16.	17.	18.	19.	20.	21.	23.	25.
340	15.	15.	16.	17.	18.	19.	20.	21.	23.	24.	26.
350	16.	16.	17.	18.	19.	20.	21.	23.	24.	26.	28.
360	17.	17.	18.	19.	20.	21.	22.	24.	25.	27.	29.
370	18.	18.	19.	20.	21.	22.	23.	25.	27.	29.	31.
380	18.	19.	20.	21.	22.	24.	25.	27.	28.	30.	33.
390	19.	20.	21.	22.	24.	25.	26.	28.	30.	32.	34.
400	20.	21.	22.	23.	25.	26.	27.	29.	31.	33.	36.
410	21.	23.	24.	25.	26.	27.	29.	31.	33.	35.	38.
420	23.	24.	25.	26.	27.	29.	30.	32.	35.	37.	40.
425 RS	23.	24.	25.	26.	28.	29.	31.	33.	35.	38.	41.
430	24.	25.	26.	27.	29.	30.	32.	34.	36.	39.	42.
440	25.	26.	27.	28.	30.	32.	33.	36.	38.	40.	44.
450	26.	27.	28.	30.	31.	33.	35.	37.	40.	42.	46.
460	27.	28.	30.	31.	33.	35.	36.	39.	42.	44.	48.
470	28.	30.	31.	32.	34.	36.	38.	41.	43.	46.	50.
480	29.	31.	32.	34.	36.	38.	40.	42.	45.	48.	52.
490	31.	32.	34.	35.	37.	39.	41.	44.	47.	50.	54.
500	32.	33.	35.	37.	39.	41.	43.	46.	49.	52.	57.
510	33.	35.	36.	38.	40.	42.	45.	48.	51.	54.	59.
520	35.	36.	38.	39.	42.	44.	46.	50.	53.	56.	61.
530	36.	38.	39.	41.	43.	46.	48.	52.	55.	59.	64.
540	37.	39.	41.	43.	45.	48.	50.	54.	57.	61.	66.
550	39.	41.	42.	44.	47.	49.	52.	56.	59.	63.	69.
560	40.	42.	44.	46.	48.	51.	54.	58.	62.	65.	71.
570	42.	44.	45.	47.	50.	53.	56.	60.	64.	68.	74.
580	43.	45.	47.	49.	52.	55.	58.	62.	66.	70.	76.
590	45.	47.	49.	51.	54.	57.	60.	64.	68.	73.	79.
600	46.	48.	50.	53.	56.	59.	62.	66.	71.	75.	82.

INITIAL STRINGING SAGS AND TENSIONS

DESIGN POINTS
CREEP IS A FACTOR

TEMP,F	ICE,IN.	WIND,PSF	FINAL SAG, FT.	FINAL TENSION, LB.	INITIAL SAG, FT.	INITIAL TENSION, LB.
30.0		9	6.47	1062.	5.94	1157.
60.0		4	4.86	649.	3.69	853.
60.0		6	5.63	733.	4.54	908.
0.0			2.28	903.	1.93	1071.
30.0			2.89	(713.)	2.20	938.
60.0			3.75	550.	2.58	798.
90.0			4.85	425.	3.14	656.
120.0			6.06	340.	3.95	523.
140.0			6.60	313.	4.62	446.
167.0			7.05	293.	5.66	365.
200.0			7.62	271.	6.98	296.
212.0			7.83	264.	7.46	277.

RULING SPAN SAGS AND TENSIONS

CONDUCTOR NO. 2 (6/1) ACSR **DESIGN RULING SPAN** 525 **FT.** **DESIGN TENSION** 1250 **LBS.**

RECOMMENDED FOR USE WITH RULING SPANS FROM 500 **FT. TO** 625 **FT.** LIGHT **LOADING DISTRICT**

	PHASE	NEUTRAL
CONDUCTOR DESC.	NO. 2(6/1) ACSR	NO. 2(6/1) ACSR
MAX. OPERATING TEMP.	120. DEGREES F	120.DEGREES F
BASIC GROUND CLEAR.	20.0 FEET	18.0 FEET
DESIGN TENSION	1226. LBS (43.0 %)	1226. LBS (43.0 %)

525. FOOT RULING SPAN LIGHT LOADING DISTRICT

FOR USE WITH A1,B1,AND C1 TYPE ASSEMBLIES

35.0 FOOT POLES QUARTER POINT OF SPAN	35.0 FOOT POLES CENTER OF SPAN	SPAN LENGTH	40.0 FOOT POLES CENTER OF SPAN	40.0 FOOT POLES QUARTER POINT OF SPAN	UPLIFT FACTOR
5.4	5.0	273.	10.0	10.4	2.6
5.0	4.5	315.	9.5	10.0	3.8
4.6	4.0	351.	9.0	9.6	5.0
4.3	3.5	372.	8.5	9.3	5.7
4.0	3.0	391.	8.0	9.0	6.4
3.7	2.5	411.	7.5	8.7	7.2
3.3	2.0	429.	7.0	8.3	8.0
3.0	1.5	447.	6.5	8.0	8.7
2.7	1.0	465.	6.0	7.7	9.5
2.3	0.5	482.	5.5	7.3	10.3
2.0	LEVEL 0.0	499.	5.0	7.0	11.1
1.7	-0.5	515.	4.5	6.7	11.9
1.3	-1.0	531.	4.0	6.3	12.7
1.0	-1.5	547.	3.5	6.0	13.6
0.7	-2.0	563.	3.0	5.7	14.4
0.3	-2.5	578.	2.5	5.3	15.2
0.0	-3.0	593.	2.0	5.0	16.1
-0.4	-3.5	607.	1.5	4.6	16.9
-0.7	-4.0	622.	1.0	4.3	17.8
-1.0	-4.5	636.	0.5	4.0	18.7
-1.4	-5.0	650.	LEVEL 0.0	3.6	19.5
-1.7	-5.5	664.	-0.5	3.3	20.4
-2.1	-6.0	677.	-1.0	2.9	21.3
-2.4	-6.5	690.	-1.5	2.6	22.2
-2.7	-7.0	703.	-2.0	2.3	23.1
-3.1	-7.5	716.	-2.5	1.9	24.0
-3.4	-8.0	729.	-3.0	1.6	24.9
-3.8	-8.5	742.	-3.5	1.2	25.8
-4.1	-9.0	754.	-4.0	0.9	26.7
-4.5	-9.5	767.	-4.5	0.5	27.6
-4.8	-10.0	779.	-5.0	0.2	28.5

ALL DISTANCES ARE IN FEET

TABLE INCLUDES A 1.0 FOOT STAKING AND CONSTRUCTION TOLERANCE IN ADDITION TO THE BASIC CLEARANCES
TABLE INCLUDES A 1.0 FOOT UPLIFT FACTOR TOLERANCE

THIS TABLE MAY BE USED FOR ANY PHASE CONDUCTOR WHOSE MAXIMUM TEMPERATURE IS 120 DEGREES F OR LESS, AND WHOSE 60 DEGREE F FINAL SAG IN A 525. FOOT SPAN IS LESS THAN OR EQUAL TO 5.6 FEET

STAKING TABLE

TEMP F	0	10	20	30	40	50	60	70	80	90	100
HORIZONTAL TENSION	1067	1024	981	938	894	849	805	760	716	672	632
SPAN FT.	STRINGING SAG-INCHES										
420	23.	24.	25.	26.	27.	29.	30.	32.	34.	36.	39.
430	24.	25.	26.	27.	28.	30.	31.	34.	36.	38.	40.
440	25.	26.	27.	28.	30.	31.	33.	35.	37.	39.	42.
450	26.	27.	28.	30.	31.	33.	34.	37.	39.	41.	44.
460	27.	28.	30.	31.	33.	34.	36.	38.	41.	43.	46.
470	28.	30.	31.	32.	34.	36.	38.	40.	43.	45.	48.
480	30.	31.	32.	34.	35.	37.	39.	42.	44.	47.	50.
490	31.	32.	34.	35.	37.	39.	41.	44.	46.	49.	53.
500	32.	34.	35.	37.	39.	41.	43.	45.	48.	51.	55.
510	33.	35.	36.	38.	40.	42.	44.	47.	50.	53.	57.
520	35.	36.	38.	39.	42.	44.	46.	49.	52.	55.	59.
525 RS	35.	37.	39.	40.	42.	45.	47.	50.	53.	56.	60.
530	36.	38.	39.	41.	43.	46.	48.	51.	54.	57.	61.
540	37.	39.	41.	43.	45.	47.	50.	53.	56.	59.	64.
550	39.	41.	42.	44.	47.	49.	51.	55.	58.	62.	66.
560	40.	42.	44.	46.	48.	51.	53.	57.	60.	64.	69.
570	42.	44.	46.	47.	50.	53.	55.	59.	63.	66.	71.
580	43.	45.	47.	49.	52.	55.	57.	61.	65.	69.	74.
590	45.	47.	49.	51.	54.	56.	59.	63.	67.	71.	76.
600	46.	48.	50.	53.	55.	58.	61.	65.	69.	73.	79.
610	48.	50.	52.	54.	57.	60.	63.	68.	72.	76.	81.
620	49.	52.	54.	56.	59.	62.	65.	70.	74.	78.	84.
630	51.	53.	56.	58.	61.	64.	68.	72.	76.	81.	87.
640	53.	55.	57.	60.	63.	66.	70.	74.	79.	84.	90.
650	54.	57.	59.	62.	65.	69.	72.	77.	81.	86.	92.
660	56.	58.	61.	64.	67.	71.	74.	79.	84.	89.	95.
670	58.	60.	63.	66.	69.	73.	76.	81.	86.	92.	98.
680	59.	62.	65.	68.	71.	75.	79.	84.	89.	94.	101.
690	61.	64.	67.	70.	73.	77.	81.	86.	92.	97.	104.
700	63.	66.	69.	72.	76.	79.	83.	89.	94.	100.	107.

INITIAL STRINGING SAGS AND TENSIONS

DESIGN POINTS

TEMP,F	ICE,IN.	WIND,PSF	FINAL SAG, FT.	FINAL TENSION, LB.	INITIAL SAG, FT.	INITIAL TENSION, LB.
CREEP IS A FACTOR						
30.0		9	9.13	1148.	8.56	1226.
60.0		4	6.98	689.	5.46	880.
60.0		6	7.97	790.	6.62	951.
0.0			3.54	888.	2.95	1067.
30.0			4.41	(713.)	3.35	938.
60.0			5.55	567.	3.91	805.
90.0			6.88	458.	4.68	672.
120.0			8.29	380.	5.71	552.
140.0			9.15	344.	6.52	483.
167.0			9.68	325.	7.72	408.
200.0			10.34	305.	9.23	341.
212.0			10.59	298.	9.77	323.

RULING SPAN SAGS AND TENSIONS

CONDUCTOR 1/0 (6/1) ACSR **DESIGN RULING SPAN** 325 **FT.** **DESIGN TENSION** 1700 **LBS.**

RECOMMENDED FOR USE WITH RULING SPANS FROM 300 **FT. TO** 425 **FT.** LIGHT **LOADING DISTRICT**

	PHASE	NEUTRAL
CONDUCTOR DESC.	1/0 (6/1) ACSR	1/0 (6/1) ACSR
MAX. OPERATING TEMP.	120. DEGREES F	120.DEGREES F
BASIC GROUND CLEAR.	20.0 FEET	18.0 FEET
DESIGN TENSION	1536. LBS (35.1 %)	1536. LBS (35.1 %)

325. FOOT RULING SPAN LIGHT LOADING DISTRICT

FOR USE WITH A1,B1,AND C1 TYPE ASSEMBLIES

35.0 FOOT POLES QUARTER POINT OF SPAN	35.0 FOOT POLES CENTER OF SPAN	SPAN LENGTH	40.0 FOOT POLES CENTER OF SPAN	40.0 FOOT POLES QUARTER POINT OF SPAN	UPLIFT FACTOR
5.4	5.0	260.	10.0	10.4	2.7
5.0	4.5	300.	9.5	10.0	3.9
4.6	4.0	335.	9.0	9.6	5.1
4.3	3.5	361.	8.5	9.3	6.1
3.9	3.0	380.	8.0	8.9	6.9
3.6	2.5	398.	7.5	8.6	7.6
3.3	2.0	416.	7.0	8.3	8.4
3.0	1.5	433.	6.5	8.0	9.2
2.6	1.0	450.	6.0	7.6	10.0
2.3	0.5	466.	5.5	7.3	10.9
2.0	LEVEL 0.0	482.	5.0	7.0	11.7
1.6	-0.5	498.	4.5	6.6	12.5
1.3	-1.0	513.	4.0	6.3	13.4
0.9	-1.5	529.	3.5	5.9	14.2
0.6	-2.0	543.	3.0	5.6	15.1
0.3	-2.5	558.	2.5	5.3	16.0
-0.1	-3.0	572.	2.0	4.9	16.8
-0.4	-3.5	586.	1.5	4.6	17.7
-0.8	-4.0	600.	1.0	4.2	18.6
-1.1	-4.5	613.	0.5	3.9	19.5
-1.4	-5.0	627.	LEVEL 0.0	3.6	20.4
-1.8	-5.5	640.	-0.5	3.2	21.3
-2.1	-6.0	653.	-1.0	2.9	22.2
-2.5	-6.5	665.	-1.5	2.5	23.1
-2.8	-7.0	678.	-2.0	2.2	24.1
-3.1	-7.5	690.	-2.5	1.9	25.0
-3.5	-8.0	702.	-3.0	1.5	25.9
-3.8	-8.5	714.	-3.5	1.2	26.8
-4.2	-9.0	726.	-4.0	0.8	27.8
-4.5	-9.5	738.	-4.5	0.5	28.7
-4.9	-10.0	750.	-5.0	0.1	29.6

ALL DISTANCES ARE IN FEET

TABLE INCLUDES A 1.0 FOOT STAKING AND CONSTRUCTION TOLERANCE IN ADDITION TO THE BASIC CLEARANCES
TABLE INCLUDES A 1.0 FOOT UPLIFT FACTOR TOLERANCE

THIS TABLE MAY BE USED FOR ANY PHASE CONDUCTOR WHOSE MAXIMUM TEMPERATURE IS 120 DEGREES F OR LESS, AND WHOSE 60 DEGREE F FINAL SAG IN A 325. FOOT SPAN IS LESS THAN OR EQUAL TO 2.3 FEET

STAKING TABLE

TEMP F	0	10	20	30	40	50	60	70	80	90	100
HORIZONTAL TENSION	1536	1468	1399	1331	1260	1189	1118	1047	975	904	837
SPAN FT.	STRINGING SAG-INCHES										
200	6.	6.	6.	7.	7.	7.	8.	8.	9.	10.	11.
210	6.	7.	7.	7.	8.	8.	9.	9.	10.	11.	12.
220	7.	7.	8.	8.	8.	9.	9.	10.	11.	12.	13.
230	8.	8.	8.	9.	9.	10.	10.	11.	12.	13.	14.
240	8.	9.	9.	9.	10.	11.	11.	12.	13.	14.	15.
250	9.	9.	10.	10.	11.	12.	12.	13.	14.	15.	16.
260	10.	10.	11.	11.	12.	12.	13.	14.	15.	16.	18.
270	10.	11.	11.	12.	13.	13.	14.	15.	16.	18.	19.
280	11.	12.	12.	13.	14.	14.	15.	16.	18.	19.	21.
290	12.	13.	13.	14.	15.	16.	16.	18.	19.	20.	22.
300	13.	13.	14.	15.	16.	17.	18.	19.	20.	22.	24.
310	14.	14.	15.	16.	17.	18.	19.	20.	22.	23.	25.
320	15.	15.	16.	17.	18.	19.	20.	22.	23.	25.	27.
325 RS	15.	16.	17.	17.	18.	19.	21.	22.	24.	25.	28.
330	15.	16.	17.	18.	19.	20.	21.	23.	25.	26.	29.
340	16.	17.	18.	19.	20.	21.	23.	24.	26.	28.	31.
350	17.	18.	19.	20.	21.	23.	24.	26.	28.	30.	32.
360	18.	19.	20.	21.	23.	24.	25.	27.	29.	31.	34.
370	19.	20.	21.	22.	24.	25.	27.	29.	31.	33.	36.
380	20.	22.	23.	24.	25.	27.	28.	30.	33.	35.	38.
390	22.	23.	24.	25.	26.	28.	30.	32.	34.	37.	40.
400	23.	24.	25.	26.	28.	30.	31.	34.	36.	39.	42.
410	24.	25.	26.	28.	29.	31.	33.	35.	38.	41.	44.
420	25.	26.	28.	29.	31.	33.	34.	37.	40.	43.	47.
430	26.	28.	29.	30.	32.	34.	36.	39.	42.	45.	49.

INITIAL STRINGING SAGS AND TENSIONS

DESIGN POINTS

TEMP,F	ICE,IN.	WIND,PSF	FINAL SAG, FT.	FINAL TENSION, LB.	INITIAL SAG, FT.	INITIAL TENSION, LB.
CREEP IS A FACTOR						
30.0		9	3.66	1380.	3.35	1504.
60.0		4	2.90	896.	2.24	1160.
60.0		6	3.34	973.	2.70	1205.
0.0			1.36	1408.	1.25	1536.
30.0			1.75	(1095.)	1.44	1331.
60.0			2.35	816.	1.72	1118.
90.0			3.20	600.	2.12	904.
120.0			4.20	457.	2.72	705.
140.0			4.60	417.	3.24	592.
167.0			4.98	386.	4.05	474.
200.0			5.46	352.	5.08	378.
212.0			5.63	341.	5.41	355.

RULING SPAN SAGS AND TENSIONS

CONDUCTOR 1/0 (6/1) ACSR **DESIGN RULING SPAN** 425 **FT.** **DESIGN TENSION** 1700 **LBS.**

RECOMMENDED FOR USE WITH RULING SPANS FROM 400 **FT. TO** 525 **FT.** LIGHT **LOADING DISTRICT**

	PHASE	NEUTRAL
CONDUCTOR DESC.	1/0 (6/1) ACSR	1/0 (6/1) ACSR
MAX. OPERATING TEMP.	120. DEGREES F	120.DEGREES F
BASIC GROUND CLEAR.	20.0 FEET	18.0 FEET
DESIGN TENSION	1591. LBS (36.3 %)	1591. LBS (36.3 %)

425. FOOT RULING SPAN LIGHT LOADING DISTRICT

FOR USE WITH A1,B1,AND C1 TYPE ASSEMBLIES

35.0 FOOT POLES QUARTER POINT OF SPAN	35.0 FOOT POLES CENTER OF SPAN	SPAN LENGTH	40.0 FOOT POLES CENTER OF SPAN	40.0 FOOT POLES QUARTER POINT OF SPAN	UPLIFT FACTOR
5.4	5.0	264.	10.0	10.4	2.8
5.0	4.5	305.	9.5	10.0	4.1
4.6	4.0	341.	9.0	9.6	5.3
4.3	3.5	365.	8.5	9.3	6.2
4.0	3.0	384.	8.0	9.0	7.0
3.6	2.5	402.	7.5	8.6	7.8
3.3	2.0	420.	7.0	8.3	8.6
3.0	1.5	438.	6.5	8.0	9.4
2.6	1.0	455.	6.0	7.6	10.3
2.3	0.5	472.	5.5	7.3	11.1
2.0	LEVEL 0.0	488.	5.0	7.0	12.0
1.6	-0.5	504.	4.5	6.6	12.8
1.3	-1.0	520.	4.0	6.3	13.7
1.0	-1.5	535.	3.5	6.0	14.6
0.6	-2.0	550.	3.0	5.6	15.5
0.3	-2.5	565.	2.5	5.3	16.4
-0.1	-3.0	579.	2.0	4.9	17.3
-0.4	-3.5	593.	1.5	4.6	18.2
-0.7	-4.0	607.	1.0	4.3	19.1
-1.1	-4.5	621.	0.5	3.9	20.0
-1.4	-5.0	635.	LEVEL 0.0	3.6	20.9
-1.8	-5.5	648.	-0.5	3.2	21.9
-2.1	-6.0	661.	-1.0	2.9	22.8
-2.4	-6.5	674.	-1.5	2.6	23.8
-2.8	-7.0	687.	-2.0	2.2	24.7
-3.1	-7.5	699.	-2.5	1.9	25.6
-3.5	-8.0	712.	-3.0	1.5	26.6
-3.8	-8.5	724.	-3.5	1.2	27.6
-4.2	-9.0	736.	-4.0	0.8	28.5
-4.5	-9.5	748.	-4.5	0.5	29.5
-4.9	-10.0	760.	-5.0	0.1	30.5

ALL DISTANCES ARE IN FEET

TABLE INCLUDES A 1.0 FOOT STAKING AND CONSTRUCTION TOLERANCE IN ADDITION TO THE BASIC CLEARANCES
TABLE INCLUDES A 1.0 FOOT UPLIFT FACTOR TOLERANCE

THIS TABLE MAY BE USED FOR ANY PHASE CONDUCTOR WHOSE MAXIMUM TEMPERATURE IS 120 DEGREES F OR LESS, AND WHOSE 60 DEGREE F FINAL SAG IN A 425. FOOT SPAN IS LESS THAN OR EQUAL TO 3.9 FEET

STAKING TABLE

TEMP F	0	10	20	30	40	50	60	70	80	90	100
HORIZONTAL TENSION	1534	1468	1402	1336	1268	1200	1133	1067	1001	936	876
SPAN FT.	STRINGING SAG-INCHES										
320	15.	15.	16.	17.	18.	19.	20.	21.	22.	24.	26.
330	15.	16.	17.	18.	19.	20.	21.	22.	24.	25.	27.
340	16.	17.	18.	19.	20.	21.	22.	24.	25.	27.	29.
350	17.	18.	19.	20.	21.	22.	24.	25.	27.	29.	31.
360	18.	19.	20.	21.	22.	24.	25.	27.	28.	30.	33.
370	19.	20.	21.	22.	24.	25.	26.	28.	30.	32.	34.
380	21.	22.	23.	24.	25.	26.	28.	30.	32.	34.	36.
390	22.	23.	24.	25.	26.	28.	29.	31.	33.	35.	38.
400	23.	24.	25.	26.	28.	29.	31.	33.	35.	37.	40.
410	24.	25.	26.	27.	29.	31.	32.	35.	37.	39.	42.
420	25.	26.	28.	29.	31.	32.	34.	36.	39.	41.	44.
425 RS	26.	27.	28.	29.	31.	33.	35.	37.	40.	42.	45.
430	26.	28.	29.	30.	32.	34.	36.	38.	41.	43.	46.
440	28.	29.	30.	32.	33.	35.	37.	40.	42.	45.	49.
450	29.	30.	32.	33.	35.	37.	39.	42.	44.	47.	51.
460	30.	32.	33.	35.	37.	39.	41.	44.	46.	49.	53.
470	31.	33.	34.	36.	38.	40.	43.	45.	48.	51.	55.
480	33.	34.	36.	38.	40.	42.	44.	47.	51.	54.	58.
490	34.	36.	37.	39.	42.	44.	46.	49.	53.	56.	60.
500	36.	37.	39.	41.	43.	46.	48.	51.	55.	58.	63.
510	37.	39.	41.	42.	45.	48.	50.	54.	57.	61.	65.
520	38.	40.	42.	44.	47.	49.	52.	56.	59.	63.	68.
530	40.	42.	44.	46.	49.	51.	54.	58.	62.	65.	71.
540	41.	43.	46.	48.	50.	53.	56.	60.	64.	68.	73.
550	43.	45.	47.	49.	52.	55.	58.	62.	66.	70.	76.
560	45.	47.	49.	51.	54.	57.	60.	65.	69.	73.	79.
570	46.	48.	51.	53.	56.	59.	63.	67.	71.	76.	82.
580	48.	50.	53.	55.	58.	61.	65.	69.	74.	78.	85.
590	49.	52.	54.	57.	60.	64.	67.	72.	76.	81.	87.
600	51.	54.	56.	59.	62.	66.	69.	74.	79.	84.	90.

INITIAL STRINGING SAGS AND TENSIONS

DESIGN POINTS TEMP,F	ICE,IN. WIND,PSF CREEP IS A FACTOR	FINAL SAG, FT.	FINAL TENSION, LB.	INITIAL SAG, FT.	INITIAL TENSION, LB.
30.0	9	5.79	1492.	5.42	1591.
60.0	4	4.66	954.	3.71	1197.
60.0	6	5.28	1054.	4.41	1262.
0.0		2.37	1387.	2.14	1534.
30.0		3.00	(1095.)	2.46	1336.
60.0		3.88	846.	2.90	1133.
90.0		4.99	658.	3.51	936.
120.0		6.19	530.	4.33	758.
140.0		6.95	473.	4.99	658.
167.0		7.41	443.	5.97	550.
200.0		7.99	412.	7.20	456.
212.0		8.20	401.	7.64	430.

RULING SPAN SAGS AND TENSIONS

CONDUCTOR 1/0 (6/1) ACSR DESIGN RULING SPAN 525 FT. DESIGN TENSION 1700 LBS.

RECOMMENDED FOR USE WITH RULING SPANS FROM 500 FT. TO 625 FT. LIGHT LOADING DISTRICT

	PHASE	NEUTRAL
CONDUCTOR DESC.	1/0 (6/1) ACSR	1/0 (6/1) ACSR
MAX. OPERATING TEMP.	120. DEGREES F	120.DEGREES F
BASIC GROUND CLEAR.	20.0 FEET	18.0 FEET
DESIGN TENSION	1675. LBS (38.2 %)	1675. LBS (38.2 %)

525. FOOT RULING SPAN LIGHT LOADING DISTRICT

FOR USE WITH A1,B1,AND C1 TYPE ASSEMBLIES

35.0 FOOT QUARTER POINT OF SPAN	POLES CENTER OF SPAN	SPAN LENGTH	40.0 FOOT CENTER OF SPAN	POLES QUARTER POINT OF SPAN	UPLIFT FACTOR
5.4	5.0	269.	10.0	10.4	2.9
5.0	4.5	310.	9.5	10.0	4.2
4.6	4.0	347.	9.0	9.6	5.5
4.3	3.5	368.	8.5	9.3	6.4
4.0	3.0	388.	8.0	9.0	7.2
3.6	2.5	406.	7.5	8.6	8.0
3.3	2.0	425.	7.0	8.3	8.8
3.0	1.5	443.	6.5	8.0	9.7
2.7	1.0	460.	6.0	7.7	10.5
2.3	0.5	477.	5.5	7.3	11.4
2.0	LEVEL 0.0	494.	5.0	7.0	12.3
1.6	-0.5	510.	4.5	6.6	13.1
1.3	-1.0	526.	4.0	6.3	14.0
1.0	-1.5	541.	3.5	6.0	14.9
0.6	-2.0	556.	3.0	5.6	15.8
0.3	-2.5	571.	2.5	5.3	16.8
0.0	-3.0	586.	2.0	5.0	17.7
-0.4	-3.5	600.	1.5	4.6	18.6
-0.7	-4.0	615.	1.0	4.3	19.6
-1.1	-4.5	629.	0.5	3.9	20.5
-1.4	-5.0	642.	LEVEL 0.0	3.6	21.5
-1.7	-5.5	656.	-0.5	3.3	22.4
-2.1	-6.0	669.	-1.0	2.9	23.4
-2.4	-6.5	682.	-1.5	2.6	24.3
-2.8	-7.0	695.	-2.0	2.2	25.3
-3.1	-7.5	708.	-2.5	1.9	26.3
-3.4	-8.0	721.	-3.0	1.6	27.3
-3.8	-8.5	733.	-3.5	1.2	28.2
-4.1	-9.0	745.	-4.0	0.9	29.2
-4.5	-9.5	757.	-4.5	0.5	30.2
-4.8	-10.0	769.	-5.0	0.2	31.2

ALL DISTANCES ARE IN FEET

TABLE INCLUDES A 1.0 FOOT STAKING AND CONSTRUCTION TOLERANCE IN ADDITION TO THE BASIC CLEARANCES
TABLE INCLUDES A 1.0 FOOT UPLIFT FACTOR TOLERANCE

THIS TABLE MAY BE USED FOR ANY PHASE CONDUCTOR WHOSE MAXIMUM TEMPERATURE IS 120 DEGREES F OR LESS, AND WHOSE 60 DEGREE F FINAL SAG IN A 525. FOOT SPAN IS LESS THAN OR EQUAL TO 5.7 FEET

STAKING TABLE

TEMP F	0	10	20	30	40	50	60	70	80	90	100
HORIZONTAL TENSION	1527	1463	1399	1336	1272	1208	1145	1084	1023	963	910
SPAN FT.					STRINGING SAG-INCHES						
420	25.	26.	28.	29.	30.	32.	34.	36.	38.	40.	43.
430	26.	28.	29.	30.	32.	34.	35.	37.	40.	42.	45.
440	28.	29.	30.	32.	33.	35.	37.	39.	42.	44.	47.
450	29.	30.	32.	33.	35.	37.	39.	41.	43.	46.	49.
460	30.	32.	33.	35.	36.	38.	40.	43.	45.	48.	51.
470	32.	33.	35.	36.	38.	40.	42.	45.	47.	50.	53.
480	33.	34.	36.	38.	40.	42.	44.	47.	49.	52.	56.
490	34.	36.	38.	39.	41.	44.	46.	49.	51.	54.	58.
500	36.	37.	39.	41.	43.	45.	48.	51.	54.	57.	60.
510	37.	39.	41.	42.	45.	47.	50.	53.	56.	59.	63.
520	39.	40.	42.	44.	47.	49.	51.	55.	58.	61.	65.
525 RS	39.	41.	43.	45.	47.	50.	52.	56.	59.	62.	67.
530	40.	42.	44.	46.	48.	51.	53.	57.	60.	64.	68.
540	42.	44.	46.	48.	50.	53.	56.	59.	63.	66.	70.
550	43.	45.	47.	49.	52.	55.	58.	61.	65.	68.	73.
560	45.	47.	49.	51.	54.	57.	60.	63.	67.	71.	76.
570	46.	49.	51.	53.	56.	59.	62.	66.	70.	74.	78.
580	48.	50.	53.	55.	58.	61.	64.	68.	72.	76.	81.
590	50.	52.	54.	57.	60.	63.	66.	70.	75.	79.	84.
600	51.	54.	56.	59.	62.	65.	69.	73.	77.	82.	87.
610	53.	56.	58.	61.	64.	67.	71.	75.	80.	84.	90.
620	55.	57.	60.	63.	66.	70.	73.	78.	82.	87.	93.
630	57.	59.	62.	65.	68.	72.	76.	80.	85.	90.	96.
640	58.	61.	64.	67.	71.	74.	78.	83.	88.	93.	99.
650	60.	63.	66.	69.	73.	77.	80.	86.	91.	96.	102.
660	62.	65.	68.	71.	75.	79.	83.	88.	93.	99.	105.
670	64.	67.	70.	73.	77.	81.	85.	91.	96.	102.	108.
680	66.	69.	72.	75.	80.	84.	88.	94.	99.	105.	112.
690	68.	71.	74.	78.	82.	86.	91.	96.	102.	108.	115.
700	70.	73.	77.	80.	84.	89.	93.	99.	105.	111.	118.

INITIAL STRINGING SAGS AND TENSIONS

DESIGN POINTS TEMP,F	ICE,IN. WIND,PSF	FINAL SAG, FT.	FINAL TENSION, LB.	INITIAL SAG, FT.	INITIAL TENSION, LB.
CREEP IS A FACTOR					
30.0	9	8.25	1597.	7.87	1675.
60.0	4	6.73	1008.	5.51	1231.
60.0	6	7.53	1128.	6.45	1316.
0.0		3.67	1363.	3.28	1527.
30.0		4.57	(1095.)	3.75	1336.
60.0		5.73	874.	4.37	1145.
90.0		7.07	709.	5.20	963.
120.0		8.46	592.	6.23	804.
140.0		9.38	535.	7.02	714.
167.0		10.14	494.	8.15	615.
200.0		10.81	464.	9.56	525.
212.0		11.05	454.	10.07	498.

RULING SPAN SAGS AND TENSIONS

CONDUCTOR 4/0 (6/1) ACSR DESIGN RULING SPAN 325 FT. DESIGN TENSION 2950 LBS.

RECOMMENDED FOR USE WITH RULING SPANS FROM 300 FT. TO 425 FT. LIGHT LOADING DISTRICT

	PHASE	NEUTRAL
CONDUCTOR DESC.	4/0 (6/1) ACSR	4/0 (6/1) ACSR
MAX. OPERATING TEMP.	120. DEGREES F	120.DEGREES F
BASIC GROUND CLEAR.	20.0 FEET	18.0 FEET
DESIGN TENSION	2950. LBS (35.3 %)	2950. LBS (35.3 %)

325. FOOT RULING SPAN LIGHT LOADING DISTRICT

FOR USE WITH A1,B1,AND C1 TYPE ASSEMBLIES

35.0 FOOT POLES QUARTER POINT OF SPAN	35.0 FOOT POLES CENTER OF SPAN	SPAN LENGTH	40.0 FOOT POLES CENTER OF SPAN	40.0 FOOT POLES QUARTER POINT OF SPAN	UPLIFT FACTOR
5.4	5.0	253.	10.0	10.4	2.7
5.0	4.5	292.	9.5	10.0	3.9
4.6	4.0	326.	9.0	9.6	5.1
4.3	3.5	355.	8.5	9.3	6.2
3.9	3.0	373.	8.0	8.9	7.0
3.6	2.5	391.	7.5	8.6	7.8
3.3	2.0	408.	7.0	8.3	8.6
2.9	1.5	425.	6.5	7.9	9.4
2.6	1.0	442.	6.0	7.6	10.2
2.3	0.5	458.	5.5	7.3	11.1
1.9	LEVEL 0.0	474.	5.0	6.9	11.9
1.6	-0.5	489.	4.5	6.6	12.8
1.3	-1.0	504.	4.0	6.3	13.6
0.9	-1.5	519.	3.5	5.9	14.5
0.6	-2.0	533.	3.0	5.6	15.4
0.2	-2.5	547.	2.5	5.2	16.2
-0.1	-3.0	561.	2.0	4.9	17.1
-0.4	-3.5	575.	1.5	4.6	18.0
-0.8	-4.0	588.	1.0	4.2	18.9
-1.1	-4.5	601.	0.5	3.9	19.8
-1.5	-5.0	614.	LEVEL 0.0	3.5	20.7
-1.8	-5.5	627.	-0.5	3.2	21.6
-2.2	-6.0	640.	-1.0	2.8	22.5
-2.5	-6.5	652.	-1.5	2.5	23.5
-2.8	-7.0	664.	-2.0	2.2	24.4
-3.2	-7.5	676.	-2.5	1.8	25.3
-3.5	-8.0	688.	-3.0	1.5	26.3
-3.9	-8.5	700.	-3.5	1.1	27.2
-4.2	-9.0	711.	-4.0	0.8	28.1
-4.6	-9.5	723.	-4.5	0.4	29.1
-4.9	-10.0	734.	-5.0	0.1	30.0

ALL DISTANCES ARE IN FEET

TABLE INCLUDES A 1.0 FOOT STAKING AND CONSTRUCTION TOLERANCE IN ADDITION TO THE BASIC CLEARANCES
TABLE INCLUDES A 1.0 FOOT UPLIFT FACTOR TOLERANCE

THIS TABLE MAY BE USED FOR ANY PHASE CONDUCTOR WHOSE MAXIMUM TEMPERATURE IS 120 DEGREES F OR LESS, AND WHOSE 60 DEGREE F FINAL SAG IN A 325. FOOT SPAN IS LESS THAN OR EQUAL TO 2.5 FEET

STAKING TABLE

STRINGING SAG-INCHES

TEMP F	0	10	20	30	40	50	60	70	80	90	100
HORIZONTAL TENSION	2950	2812	2674	2536	2393	2250	2108	1967	1826	1686	1559
SPAN FT.											
200	6.	6.	7.	7.	7.	8.	8.	9.	10.	10.	11.
210	7.	7.	7.	8.	8.	9.	9.	10.	11.	11.	13.
220	7.	8.	8.	8.	9.	9.	10.	11.	12.	13.	14.
230	8.	8.	9.	9.	10.	10.	11.	12.	13.	14.	15.
240	9.	9.	9.	10.	11.	11.	12.	13.	14.	15.	16.
250	9.	10.	10.	11.	11.	12.	13.	14.	15.	16.	18.
260	10.	11.	11.	12.	12.	13.	14.	15.	16.	18.	19.
270	11.	11.	12.	13.	13.	14.	15.	16.	18.	19.	21.
280	12.	12.	13.	14.	14.	15.	16.	18.	19.	20.	22.
290	12.	13.	14.	14.	15.	16.	17.	19.	20.	22.	24.
300	13.	14.	15.	15.	17.	18.	19.	20.	22.	23.	26.
310	14.	15.	16.	17.	18.	19.	20.	22.	23.	25.	27.
320	15.	16.	17.	18.	19.	20.	21.	23.	25.	27.	29.
325 RS	16.	16.	17.	18.	19.	21.	22.	24.	26.	27.	30.
330	16.	17.	18.	19.	20.	21.	23.	24.	26.	28.	31.
340	17.	18.	19.	20.	21.	23.	24.	26.	28.	30.	33.
350	18.	19.	20.	21.	23.	24.	25.	27.	30.	32.	35.
360	19.	20.	21.	22.	24.	25.	27.	29.	31.	34.	37.
370	20.	21.	22.	24.	25.	27.	28.	31.	33.	35.	39.
380	21.	23.	24.	25.	27.	28.	30.	32.	35.	37.	41.
390	23.	24.	25.	26.	28.	30.	32.	34.	37.	39.	43.
400	24.	25.	26.	28.	29.	31.	33.	36.	39.	41.	45.
410	25.	26.	28.	29.	31.	33.	35.	38.	41.	44.	48.
420	26.	28.	29.	30.	32.	34.	37.	40.	43.	46.	50.
430	27.	29.	30.	32.	34.	36.	38.	42.	45.	48.	53.

INITIAL STRINGING SAGS AND TENSIONS

DESIGN POINTS TEMP,F	ICE,IN.	WIND,PSF	FINAL SAG, FT.	FINAL TENSION, LB.	INITIAL SAG, FT.	INITIAL TENSION, LB.
CREEP IS A FACTOR						
30.0		9	3.07	2423.	2.72	2733.
60.0		4	2.79	1638.	2.12	2156.
60.0		6	3.09	1734.	2.42	2212.
0.0			1.42	2707.	1.30	2950.
30.0			1.84	(2088.)	1.52	2536.
60.0			2.48	1548.	1.82	2108.
90.0			3.37	1141.	2.28	1686.
120.0			4.38	879.	2.94	1307.
140.0			4.78	805.	3.50	1100.
167.0			5.16	745.	4.33	889.
200.0			5.64	682.	5.35	719.
212.0			5.82	662.	5.61	686.

RULING SPAN SAGS AND TENSIONS

CONDUCTOR 4/0 (6/1) ACSR DESIGN RULING SPAN 425 FT. DESIGN TENSION 2950 LBS.

RECOMMENDED FOR USE WITH RULING SPANS FROM 400 FT. TO 525 FT. LIGHT LOADING DISTRICT

	PHASE	NEUTRAL
CONDUCTOR DESC.	4/0 (6/1) ACSR	4/0 (6/1) ACSR
MAX. OPERATING TEMP.	120. DEGREES F	120.DEGREES F
BASIC GROUND CLEAR.	20.0 FEET	18.0 FEET
DESIGN TENSION	2944. LBS (35.3 %)	2944. LBS (35.3 %)

425. FOOT RULING SPAN LIGHT LOADING DISTRICT

FOR USE WITH A1,B1,AND C1 TYPE ASSEMBLIES

35.0 FOOT POLES QUARTER POINT OF SPAN	35.0 FOOT POLES CENTER OF SPAN	SPAN LENGTH	40.0 FOOT POLES CENTER OF SPAN	40.0 FOOT POLES QUARTER POINT OF SPAN	UPLIFT FACTOR
5.4	5.0	258.	10.0	10.4	2.8
5.0	4.5	298.	9.5	10.0	4.1
4.6	4.0	333.	9.0	9.6	5.3
4.3	3.5	359.	8.5	9.3	6.4
3.9	3.0	378.	8.0	8.9	7.2
3.6	2.5	396.	7.5	8.6	8.0
3.3	2.0	414.	7.0	8.3	8.8
3.0	1.5	431.	6.5	8.0	9.6
2.6	1.0	448.	6.0	7.6	10.4
2.3	0.5	464.	5.5	7.3	11.3
1.9	LEVEL 0.0	480.	5.0	6.9	12.2
1.6	-0.5	495.	4.5	6.6	13.0
1.3	-1.0	511.	4.0	6.3	13.9
0.9	-1.5	526.	3.5	5.9	14.8
0.6	-2.0	540.	3.0	5.6	15.7
0.3	-2.5	555.	2.5	5.3	16.6
-0.1	-3.0	569.	2.0	4.9	17.5
-0.4	-3.5	583.	1.5	4.6	18.4
-0.8	-4.0	596.	1.0	4.2	19.3
-1.1	-4.5	610.	0.5	3.9	20.3
-1.4	-5.0	623.	LEVEL 0.0	3.6	21.2
-1.8	-5.5	636.	-0.5	3.2	22.1
-2.1	-6.0	649.	-1.0	2.9	23.1
-2.5	-6.5	662.	-1.5	2.5	24.0
-2.8	-7.0	674.	-2.0	2.2	25.0
-3.2	-7.5	686.	-2.5	1.8	25.9
-3.5	-8.0	698.	-3.0	1.5	26.9
-3.8	-8.5	710.	-3.5	1.2	27.8
-4.2	-9.0	722.	-4.0	0.8	28.8
-4.5	-9.5	734.	-4.5	0.5	29.8
-4.9	-10.0	745.	-5.0	0.1	30.7

ALL DISTANCES ARE IN FEET

TABLE INCLUDES A 1.0 FOOT STAKING AND CONSTRUCTION TOLERANCE IN ADDITION TO THE BASIC CLEARANCES
TABLE INCLUDES A 1.0 FOOT UPLIFT FACTOR TOLERANCE

THIS TABLE MAY BE USED FOR ANY PHASE CONDUCTOR WHOSE MAXIMUM TEMPERATURE IS 120 DEGREES F OR LESS, AND WHOSE 60 DEGREE F FINAL SAG IN A 425. FOOT SPAN IS LESS THAN OR EQUAL TO 4.1 FEET

STAKING TABLE

TEMP F	0	10	20	30	40	50	60	70	80	90	100
HORIZONTAL TENSION	2944	2810	2677	2544	2409	2275	2141	2012	1883	1754	1642
SPAN FT.	STRINGING SAG-INCHES										
320	15.	16.	17.	18.	19.	20.	21.	22.	24.	25.	28.
330	16.	17.	18.	19.	20.	21.	22.	24.	25.	27.	29.
340	17.	18.	19.	20.	21.	22.	24.	25.	27.	29.	31.
350	18.	19.	20.	21.	22.	24.	25.	27.	29.	30.	33.
360	19.	20.	21.	22.	24.	25.	26.	28.	30.	32.	35.
370	20.	21.	22.	24.	25.	26.	28.	30.	32.	34.	37.
380	21.	23.	24.	25.	26.	28.	29.	32.	34.	36.	39.
390	23.	24.	25.	26.	28.	29.	31.	33.	36.	38.	41.
400	24.	25.	26.	27.	29.	31.	33.	35.	37.	40.	43.
410	25.	26.	28.	29.	31.	32.	34.	37.	39.	42.	45.
420	26.	28.	29.	30.	32.	34.	36.	39.	41.	44.	47.
425 RS	27.	28.	30.	31.	33.	35.	37.	40.	42.	45.	49.
430	27.	29.	30.	32.	34.	36.	38.	40.	43.	46.	50.
440	29.	30.	32.	33.	35.	37.	39.	42.	45.	48.	52.
450	30.	32.	33.	35.	37.	39.	41.	44.	47.	50.	54.
460	31.	33.	35.	36.	39.	41.	43.	46.	50.	53.	57.
470	33.	34.	36.	38.	40.	43.	45.	48.	52.	55.	59.
480	34.	36.	38.	40.	42.	45.	47.	50.	54.	57.	62.
490	36.	37.	39.	41.	44.	46.	49.	53.	56.	60.	64.
500	37.	39.	41.	43.	46.	48.	51.	55.	58.	62.	67.
510	39.	41.	43.	45.	47.	50.	53.	57.	61.	65.	70.
520	40.	42.	44.	46.	49.	52.	55.	59.	63.	67.	73.
530	42.	44.	46.	48.	51.	54.	57.	62.	66.	70.	75.
540	43.	46.	48.	50.	53.	56.	59.	64.	68.	73.	78.
550	45.	47.	50.	52.	55.	58.	62.	66.	71.	75.	81.
560	47.	49.	51.	54.	57.	61.	64.	69.	73.	78.	84.
570	48.	51.	53.	56.	59.	63.	66.	71.	76.	81.	87.
580	50.	53.	55.	58.	61.	65.	69.	74.	79.	84.	90.
590	52.	54.	57.	60.	64.	67.	71.	76.	81.	87.	94.
600	53.	56.	59.	62.	66.	70.	73.	79.	84.	90.	97.

INITIAL STRINGING SAGS AND TENSIONS

DESIGN POINTS TEMP,F	ICE,IN. WIND,PSF	FINAL SAG, FT.	FINAL TENSION, LB.	INITIAL SAG, FT.	INITIAL TENSION, LB.
CREEP IS A FACTOR					
30.0	9	4.96	2565.	4.47	2843.
60.0	4	4.51	1733.	3.53	2214.
60.0	6	4.92	1858.	3.99	2294.
0.0		2.47	2659.	2.23	2944.
30.0		3.15	(2088.)	2.58	2544.
60.0		4.08	1612.	3.07	2141.
90.0		5.22	1260.	3.75	1755.
120.0		6.43	1023.	4.63	1419.
140.0		7.18	917.	5.32	1236.
167.0		7.65	861.	6.32	1042.
200.0		8.22	801.	7.54	873.
212.0		8.43	781.	7.97	826.

RULING SPAN SAGS AND TENSIONS

CONDUCTOR 4/0 (6/1) ACSR **DESIGN RULING SPAN** 525 **FT. DESIGN TENSION** 2950 **LBS.**

RECOMMENDED FOR USE WITH RULING SPANS FROM 500 **FT. TO** 625 **FT.** LIGHT **LOADING DISTRICT**

	PHASE	NEUTRAL
CONDUCTOR DESC.	4/0 (6/1) ACSR	4/0 (6/1) ACSR
MAX. OPERATING TEMP.	120. DEGREES F	120.DEGREES F
BASIC GROUND CLEAR.	20.0 FEET	18.0 FEET
DESIGN TENSION	2948. LBS (35.3 %)	2948. LBS (35.3 %)

525. FOOT RULING SPAN LIGHT LOADING DISTRICT

FOR USE WITH A1,B1,AND C1 TYPE ASSEMBLIES

35.0 FOOT POLES QUARTER POINT OF SPAN	35.0 FOOT POLES CENTER OF SPAN	SPAN LENGTH	40.0 FOOT POLES CENTER OF SPAN	40.0 FOOT POLES QUARTER POINT OF SPAN	UPLIFT FACTOR
5.4	5.0	262.	10.0	10.4	2.9
5.0	4.5	303.	9.5	10.0	4.3
4.6	4.0	339.	9.0	9.6	5.6
4.3	3.5	363.	8.5	9.3	6.5
4.0	3.0	382.	8.0	9.0	7.4
3.6	2.5	400.	7.5	8.6	8.2
3.3	2.0	418.	7.0	8.3	9.0
3.0	1.5	436.	6.5	8.0	9.9
2.6	1.0	453.	6.0	7.6	10.8
2.3	0.5	469.	5.5	7.3	11.6
2.0	LEVEL 0.0	486.	5.0	7.0	12.5
1.6	-0.5	502.	4.5	6.6	13.4
1.3	-1.0	517.	4.0	6.3	14.3
1.0	-1.5	532.	3.5	6.0	15.2
0.6	-2.0	547.	3.0	5.6	16.2
0.3	-2.5	562.	2.5	5.3	17.1
-0.1	-3.0	576.	2.0	4.9	18.0
-0.4	-3.5	590.	1.5	4.6	19.0
-0.7	-4.0	604.	1.0	4.3	19.9
-1.1	-4.5	618.	0.5	3.9	20.9
-1.4	-5.0	631.	LEVEL 0.0	3.6	21.8
-1.8	-5.5	644.	-0.5	3.2	22.8
-2.1	-6.0	657.	-1.0	2.9	23.8
-2.4	-6.5	670.	-1.5	2.6	24.8
-2.8	-7.0	683.	-2.0	2.2	25.7
-3.1	-7.5	695.	-2.5	1.9	26.7
-3.5	-8.0	708.	-3.0	1.5	27.7
-3.8	-8.5	720.	-3.5	1.2	28.7
-4.2	-9.0	732.	-4.0	0.8	29.7
-4.5	-9.5	744.	-4.5	0.5	30.7
-4.9	-10.0	755.	-5.0	0.1	31.7

ALL DISTANCES ARE IN FEET

TABLE INCLUDES A 1.0 FOOT STAKING AND CONSTRUCTION TOLERANCE IN ADDITION TO THE BASIC CLEARANCES
TABLE INCLUDES A 1.0 FOOT UPLIFT FACTOR TOLERANCE

THIS TABLE MAY BE USED FOR ANY PHASE CONDUCTOR WHOSE MAXIMUM TEMPERATURE IS 120 DEGREES F OR LESS, AND WHOSE 60 DEGREE F FINAL SAG IN A 525. FOOT SPAN IS LESS THAN OR EQUAL TO 6.0 FEET

STAKING TABLE

TEMP F	0	10	20	30	40	50	60	70	80	90	100
HORIZONTAL TENSION	2924	2796	2669	2541	2416	2290	2164	2048	1931	1814	1714
SPAN FT.	STRINGING SAG-INCHES										
420	26.	28.	29.	30.	32.	34.	36.	38.	40.	42.	45.
430	28.	29.	30.	32.	34.	35.	37.	40.	42.	45.	47.
440	29.	30.	32.	33.	35.	37.	39.	42.	44.	47.	50.
450	30.	32.	33.	35.	37.	39.	41.	43.	46.	49.	52.
460	32.	33.	35.	36.	38.	41.	43.	45.	48.	51.	54.
470	33.	35.	36.	38.	40.	42.	45.	47.	50.	53.	57.
480	34.	36.	38.	40.	42.	44.	46.	49.	52.	55.	59.
490	36.	38.	39.	41.	44.	46.	48.	52.	55.	58.	62.
500	37.	39.	41.	43.	45.	48.	50.	54.	57.	60.	64.
510	39.	41.	43.	45.	47.	50.	52.	56.	59.	63.	67.
520	40.	42.	44.	46.	49.	52.	55.	58.	62.	65.	69.
525 RS	41.	43.	45.	47.	50.	53.	56.	59.	63.	66.	71.
530	42.	44.	46.	48.	51.	54.	57.	60.	64.	68.	72.
540	44.	46.	48.	50.	53.	56.	59.	63.	66.	70.	75.
550	45.	47.	50.	52.	55.	58.	61.	65.	69.	73.	78.
560	47.	49.	52.	54.	57.	60.	63.	67.	71.	75.	80.
570	49.	51.	53.	56.	59.	62.	66.	70.	74.	78.	83.
580	50.	53.	55.	58.	61.	65.	68.	72.	77.	81.	86.
590	52.	55.	57.	60.	63.	67.	70.	75.	79.	84.	89.
600	54.	56.	59.	62.	65.	69.	73.	77.	82.	87.	92.
610	56.	58.	61.	64.	68.	71.	75.	80.	85.	90.	95.
620	57.	60.	63.	66.	70.	74.	78.	83.	88.	93.	99.
630	59.	62.	65.	68.	72.	76.	80.	85.	90.	96.	102.
640	61.	64.	67.	70.	74.	79.	83.	88.	93.	99.	105.
650	63.	66.	69.	73.	77.	81.	85.	91.	96.	102.	108.
660	65.	68.	72.	75.	79.	84.	88.	94.	99.	105.	112.
670	67.	70.	74.	77.	82.	86.	91.	96.	102.	108.	115.
680	69.	73.	76.	79.	84.	89.	93.	99.	105.	111.	119.
690	71.	75.	78.	82.	87.	91.	96.	102.	108.	115.	122.
700	73.	77.	81.	84.	89.	94.	99.	105.	112.	118.	126.

INITIAL STRINGING SAGS AND TENSIONS

DESIGN POINTS

CREEP IS A FACTOR

TEMP,F	ICE,IN.	WIND,PSF	FINAL SAG, FT.	FINAL TENSION, LB.	INITIAL SAG, FT.	INITIAL TENSION, LB.
30.0		9	7.19	2698.	6.58	2948.
60.0		4	6.57	1819.	5.27	2264.
60.0		6	7.09	1970.	5.89	2370.
0.0			3.85	2607.	3.43	2924.
30.0			4.81	(2088.)	3.95	2542.
60.0			6.01	1670.	4.63	2165.
90.0			7.37	1362.	5.53	1815.
120.0			8.76	1146.	6.63	1515.
140.0			9.67	1039.	7.44	1350.
167.0			10.44	963.	8.58	1171.
200.0			11.10	906.	9.98	1007.
212.0			11.34	887.	10.48	959.

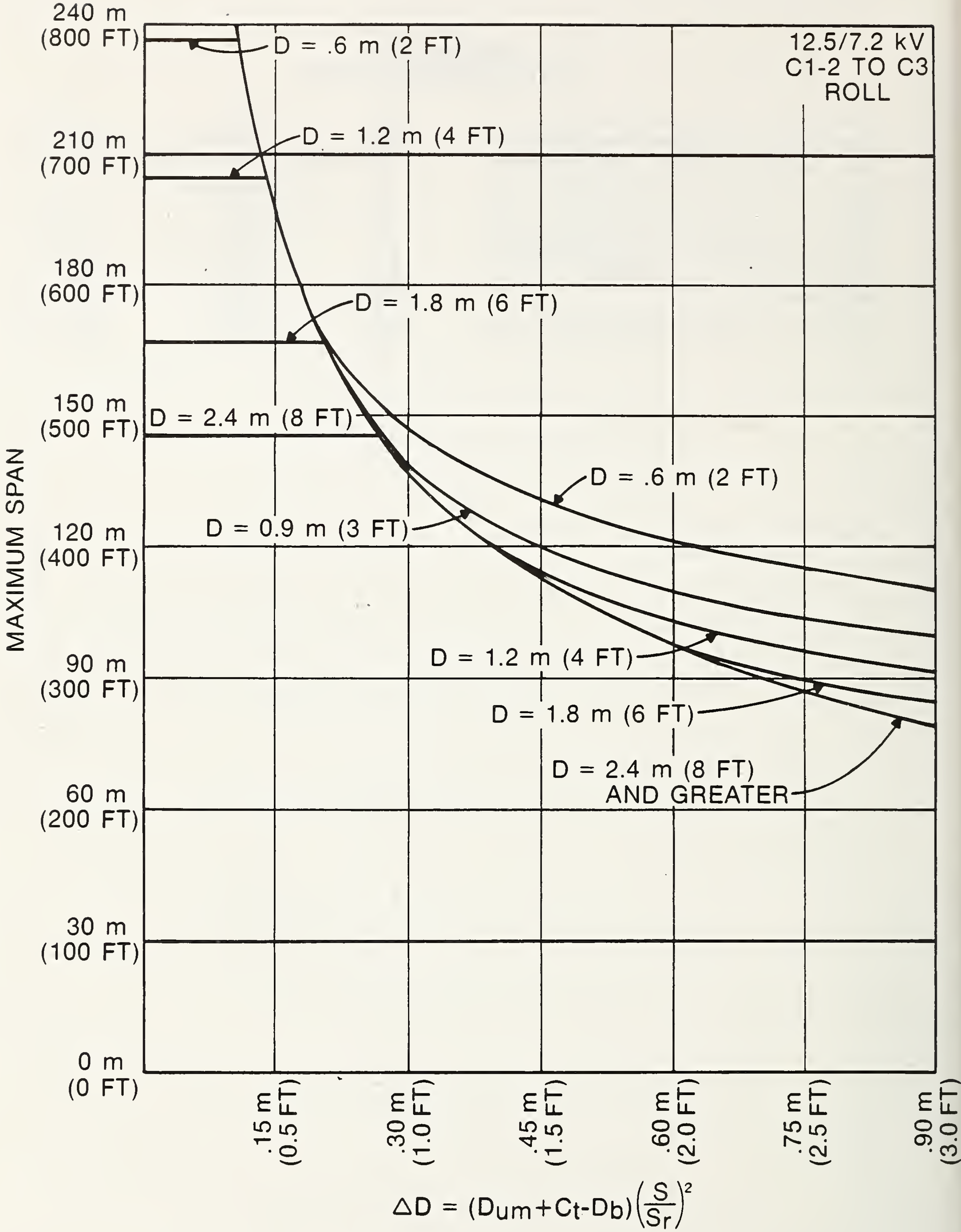
RULING SPAN SAGS AND TENSIONS

APPENDIX D
MAXIMUM SPAN CHARTS

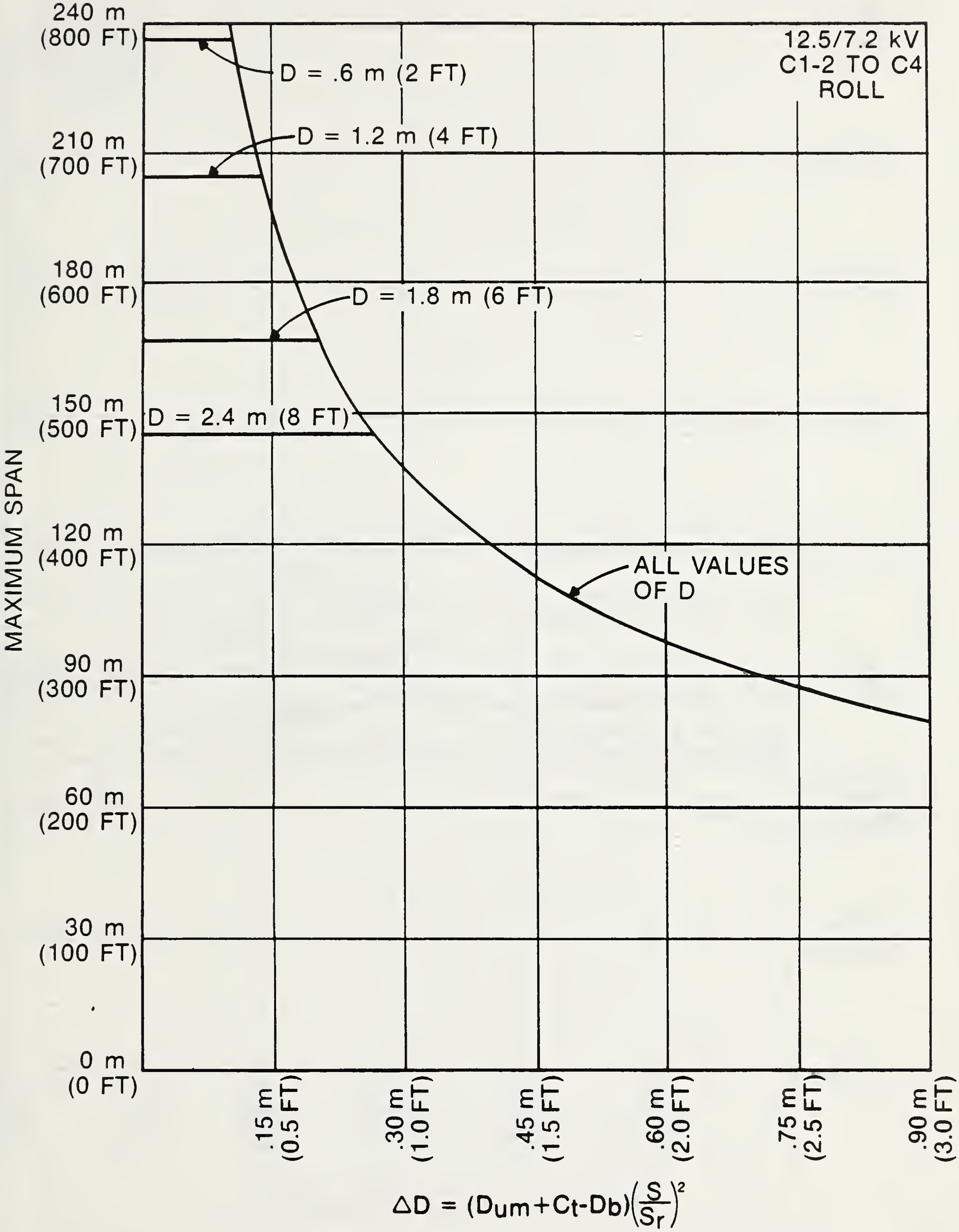
The maximum span charts included in Appendix D are for use in determining the approximate maximum allowable spans for selected spans in which the conductor rolls from one configuration to another between structures. The span limit is determined as a function of the conductor separations. The method for applying the charts is described in Chapter V-6 of this design manual.

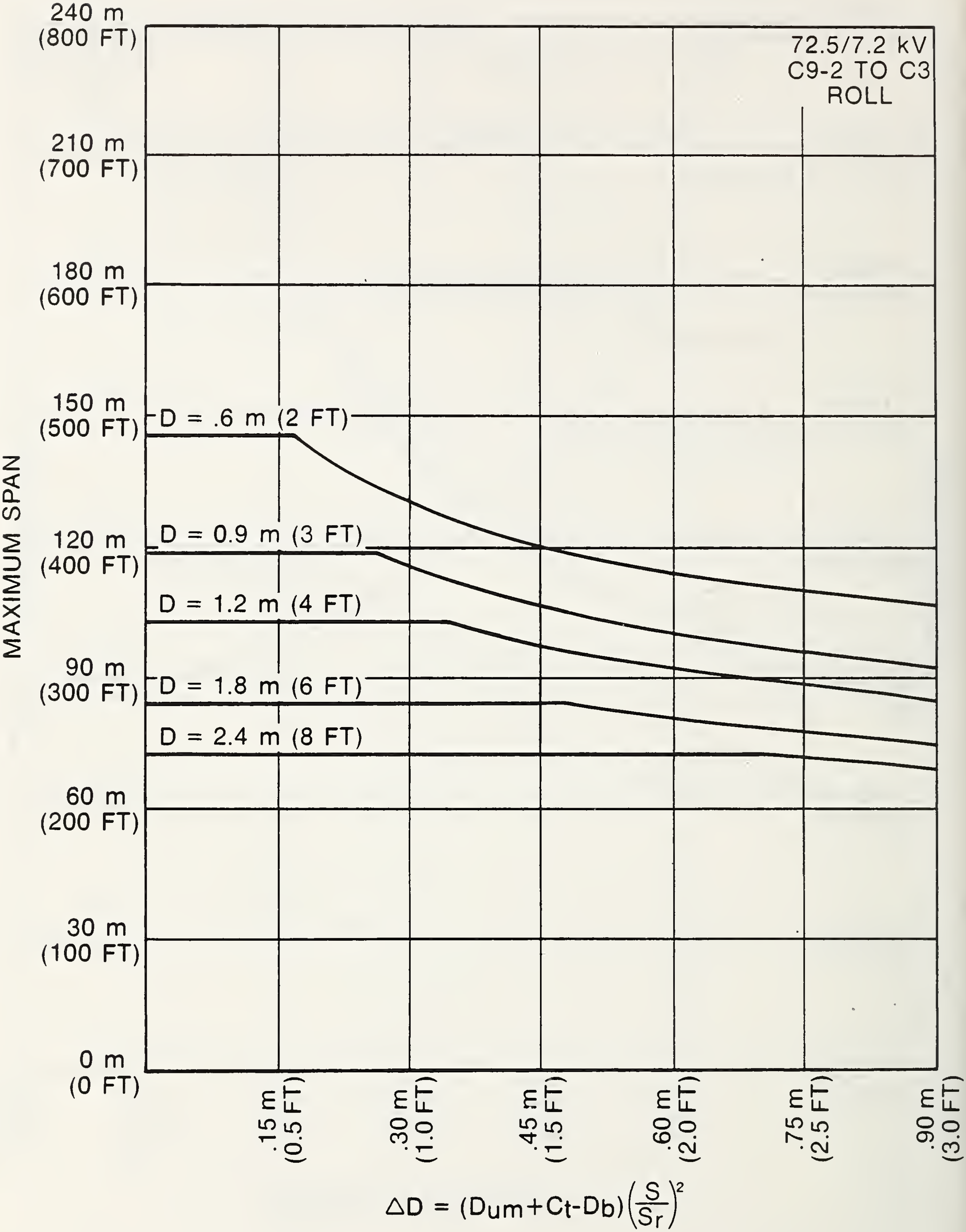
Charts are included for the conductor rolls listed.

Chart Page	Line Voltage	Roll Description
D-2	12.5/7.2 kV	C1-2-C3
D-3	12.5/7.2	C1-2-C4
D-4	12.5/7.2	C9-2-C3
D-5	12.5/7.2	C9-2-C4
D-6	24.9/14.4	VC1-2-VC3
D-7	24.9/14.4	VC1-2-VC4
D-8	24.9/14.4	VC9-2-VC3
D-9	24.9/14.4	VC9-2-VC4

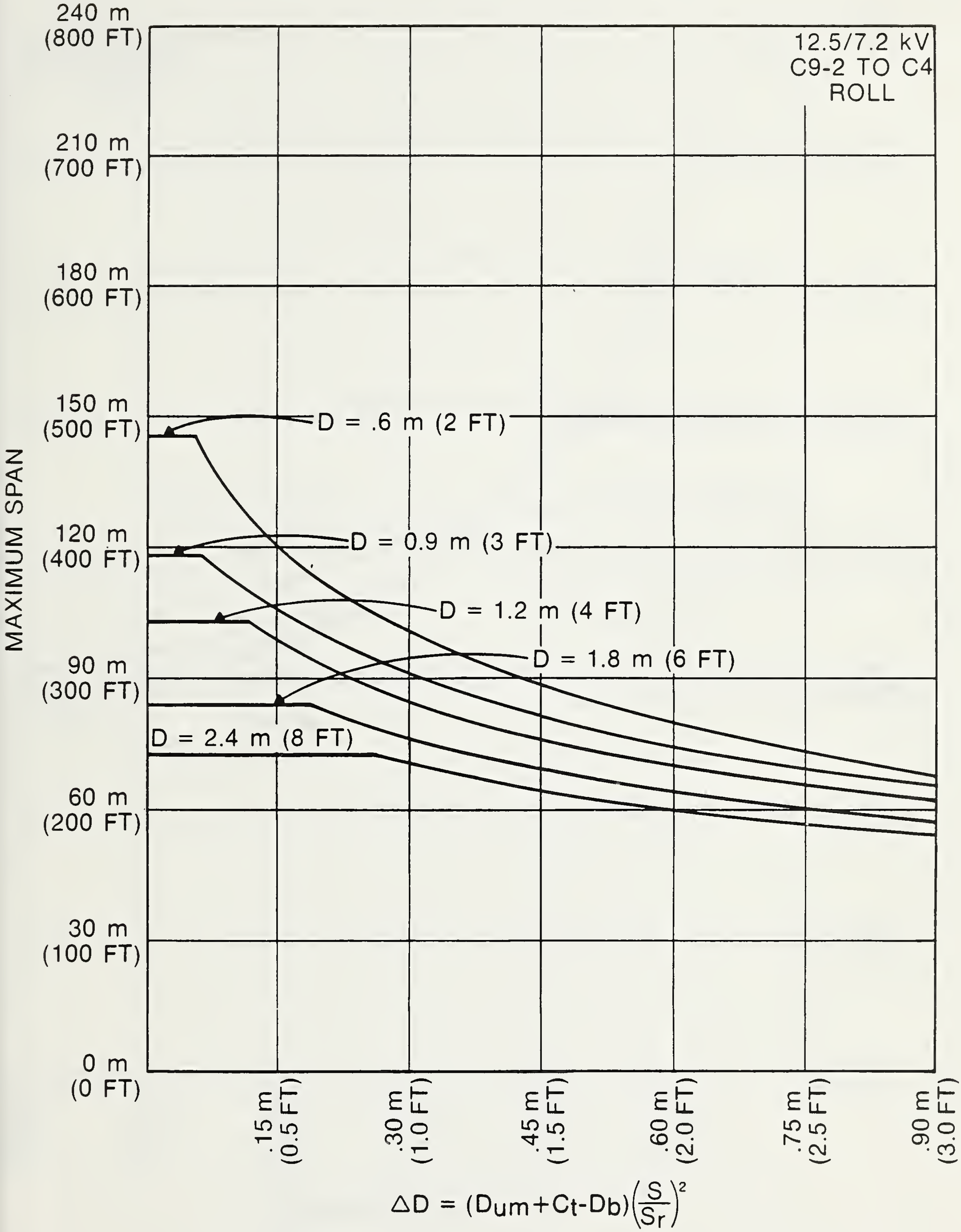


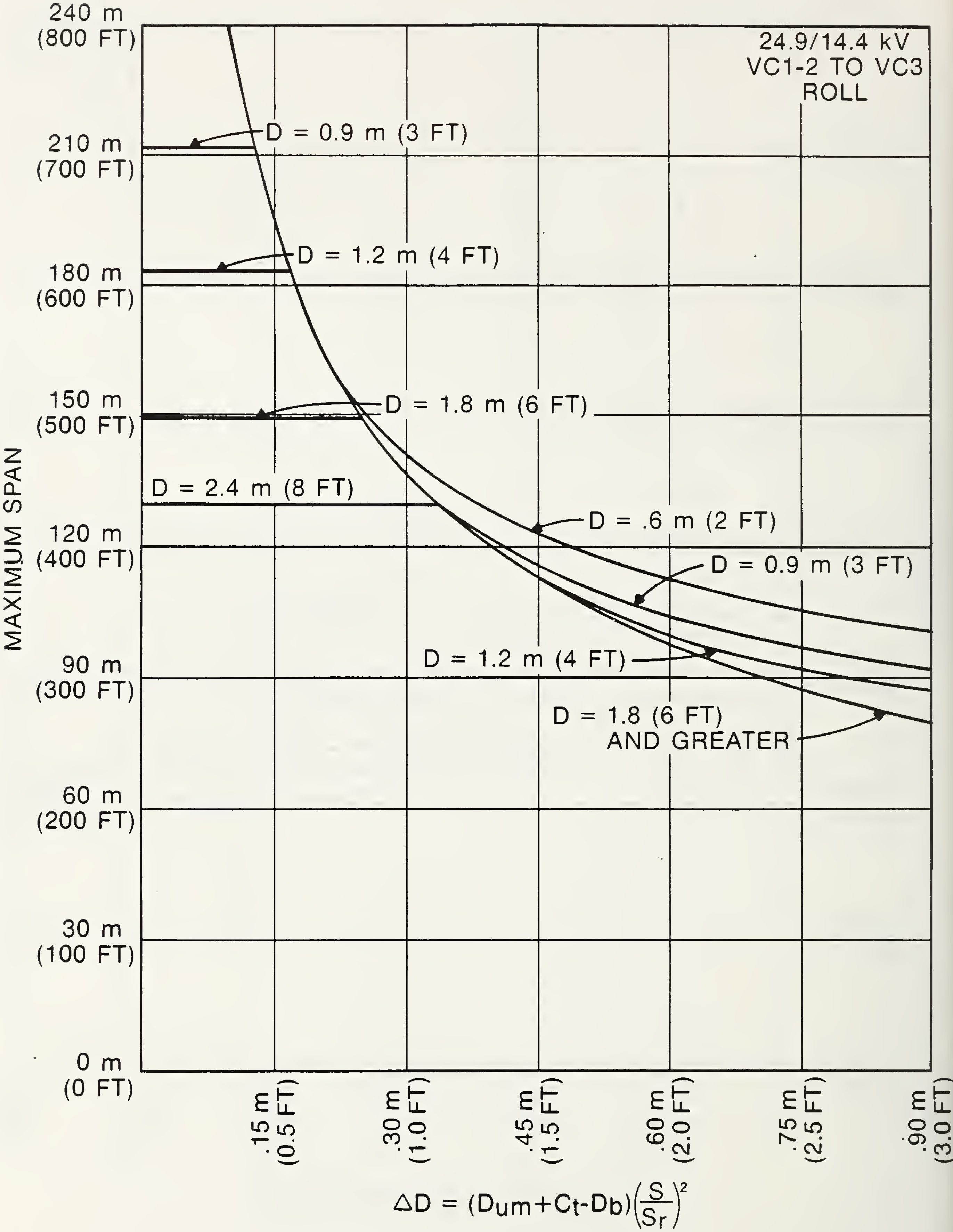
12.5/7.2 kV
C1-2 TO C3
ROLL
MAXIMUM SPAN
240 m (800 FT)
210 m (700 FT)
180 m (600 FT)
150 m (500 FT)
120 m (400 FT)
90 m (300 FT)
60 m (200 FT)
30 m (100 FT)
0 m (0 FT)
D = .6 m (2 FT)
D = 1.2 m (4 FT)
D = 1.8 m (6 FT)
D = 2.4 m (8 FT)
D = .6 m (2 FT)
D = 0.9 m (3 FT)
D = 1.2 m (4 FT)
D = 1.8 m (6 FT)
D = 2.4 m (8 FT) AND GREATER
.15 m (0.5 FT)
.30 m (1.0 FT)
.45 m (1.5 FT)
.60 m (2.0 FT)
.75 m (2.5 FT)
.90 m (3.0 FT)
$\Delta D = (D_{um} + C_t - D_b)\left(\frac{S}{S_r}\right)^2$

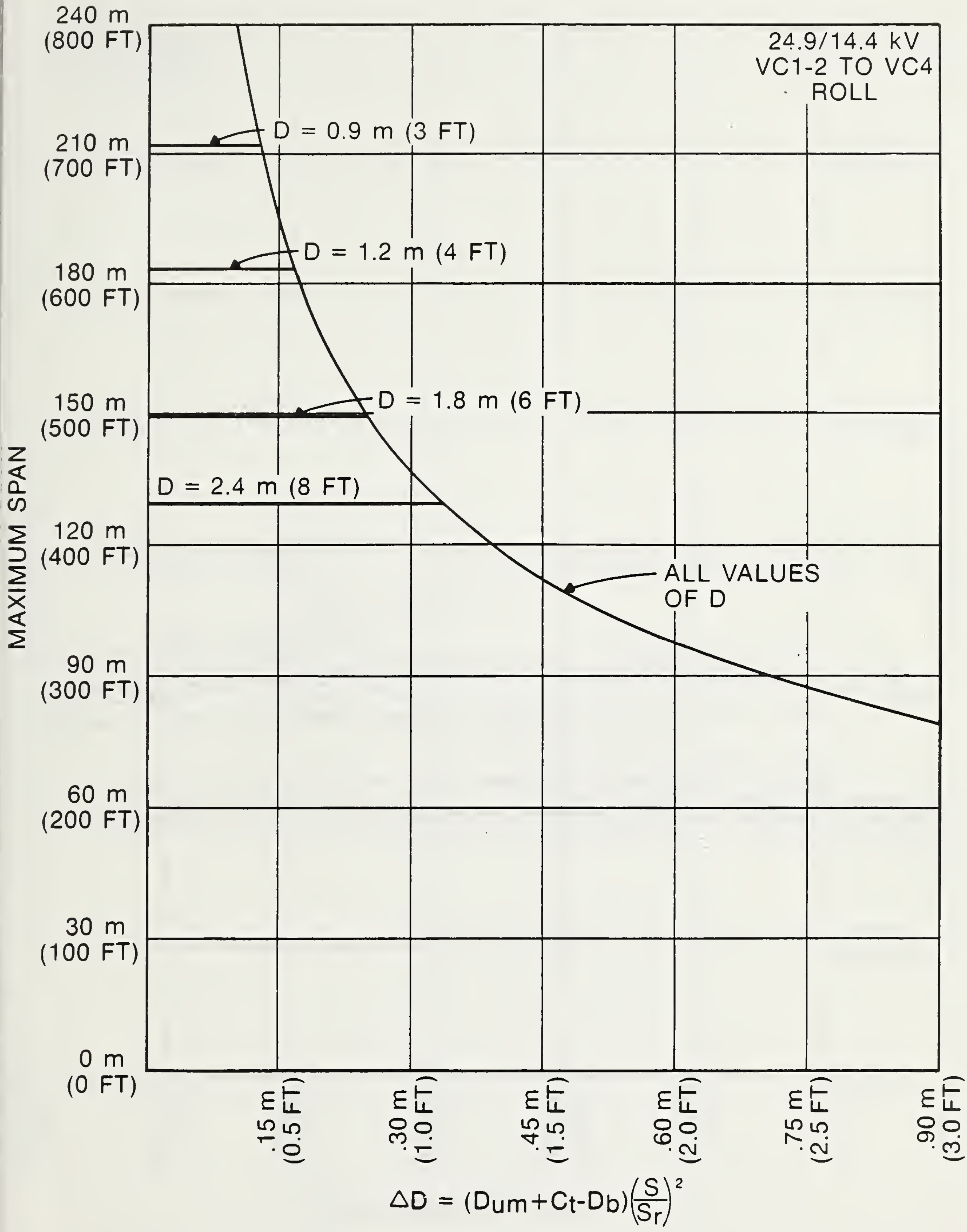

12.5/7.2 kV
C1-2 TO C4
ROLL
D = .6 m (2 FT)
D = 1.2 m (4 FT)
D = 1.8 m (6 FT)
D = 2.4 m (8 FT)
ALL VALUES OF D
MAXIMUM SPAN
240 m (800 FT)
210 m (700 FT)
180 m (600 FT)
150 m (500 FT)
120 m (400 FT)
90 m (300 FT)
60 m (200 FT)
30 m (100 FT)
0 m (0 FT)
.15 m (0.5 FT)
.30 m (1.0 FT)
.45 m (1.5 FT)
.60 m (2.0 FT)
.75 m (2.5 FT)
.90 m (3.0 FT)
$\Delta D = (D_{um} + C_t - D_b)\left(\frac{S}{S_r}\right)^2$

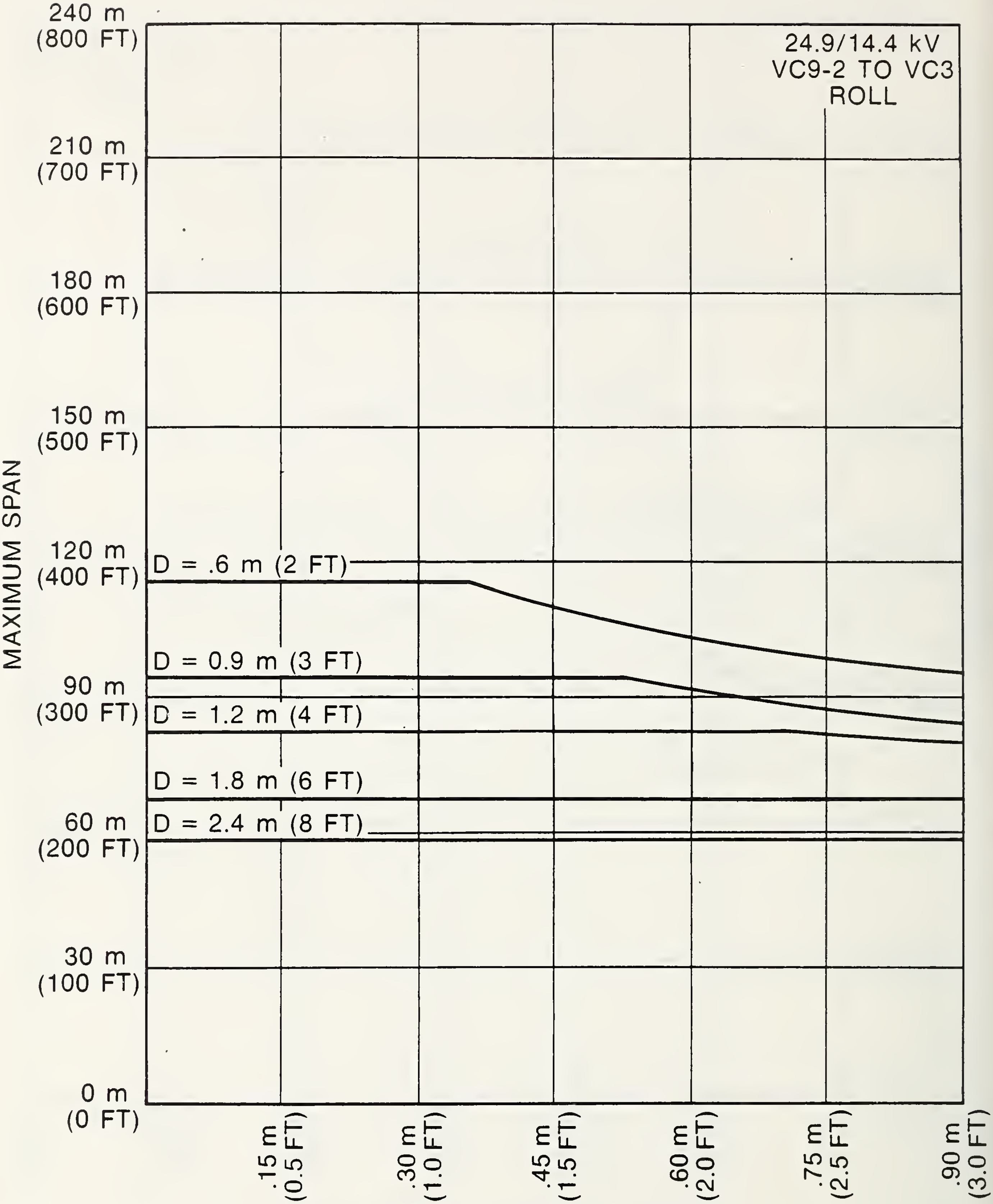


72.5/7.2 kV
C9-2 TO C3
ROLL
MAXIMUM SPAN
240 m (800 FT)
210 m (700 FT)
180 m (600 FT)
150 m (500 FT)
120 m (400 FT)
90 m (300 FT)
60 m (200 FT)
30 m (100 FT)
0 m (0 FT)
D = .6 m (2 FT)
D = 0.9 m (3 FT)
D = 1.2 m (4 FT)
D = 1.8 m (6 FT)
D = 2.4 m (8 FT)
.15 m (0.5 FT)
.30 m (1.0 FT)
.45 m (1.5 FT)
.60 m (2.0 FT)
.75 m (2.5 FT)
.90 m (3.0 FT)
$\Delta D = (D_{um} + C_t - D_b)\left(\frac{S}{S_r}\right)^2$

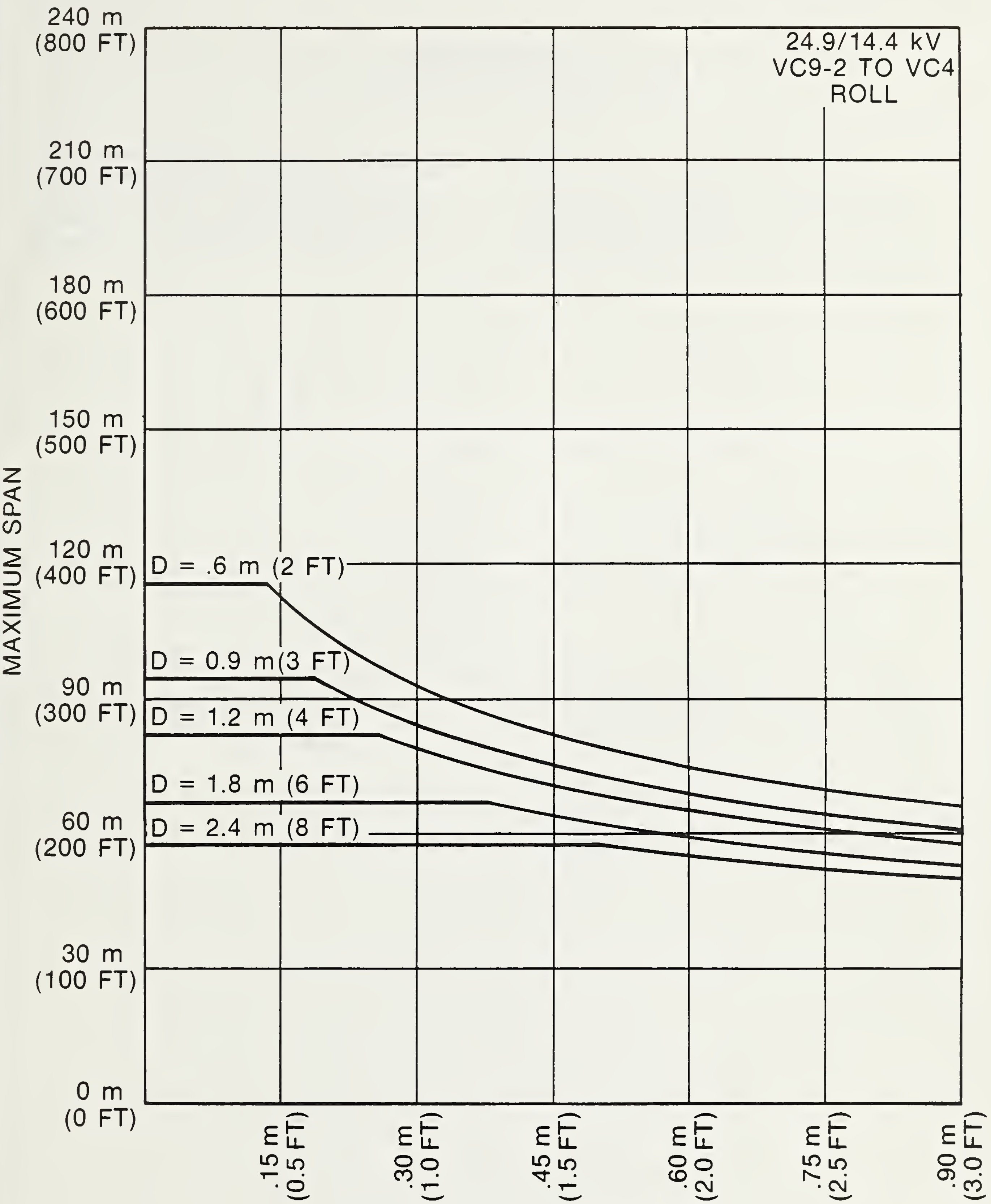

12.5/7.2 kV
C9-2 TO C4
ROLL
MAXIMUM SPAN
240 m (800 FT)
210 m (700 FT)
180 m (600 FT)
150 m (500 FT)
120 m (400 FT)
90 m (300 FT)
60 m (200 FT)
30 m (100 FT)
0 m (0 FT)
D = .6 m (2 FT)
D = 0.9 m (3 FT)
D = 1.2 m (4 FT)
D = 1.8 m (6 FT)
D = 2.4 m (8 FT)
.15 m (0.5 FT)
.30 m (1.0 FT)
.45 m (1.5 FT)
.60 m (2.0 FT)
.75 m (2.5 FT)
.90 m (3.0 FT)
$\Delta D = (D_{um} + C_t - D_b)\left(\frac{S}{S_r}\right)^2$


24.9/14.4 kV
VC1-2 TO VC3
ROLL
MAXIMUM SPAN
240 m (800 FT)
210 m (700 FT)
180 m (600 FT)
150 m (500 FT)
120 m (400 FT)
90 m (300 FT)
60 m (200 FT)
30 m (100 FT)
0 m (0 FT)
D = 0.9 m (3 FT)
D = 1.2 m (4 FT)
D = 1.8 m (6 FT)
D = 2.4 m (8 FT)
D = .6 m (2 FT)
D = 0.9 m (3 FT)
D = 1.2 m (4 FT)
D = 1.8 (6 FT)
AND GREATER
.15 m (0.5 FT)
.30 m (1.0 FT)
.45 m (1.5 FT)
.60 m (2.0 FT)
.75 m (2.5 FT)
.90 m (3.0 FT)
$\Delta D = (D_{um} + C_t - D_b)\left(\frac{S}{S_r}\right)^2$


24.9/14.4 kV
VC1-2 TO VC4
ROLL
D = 0.9 m (3 FT)
D = 1.2 m (4 FT)
D = 1.8 m (6 FT)
D = 2.4 m (8 FT)
ALL VALUES OF D
MAXIMUM SPAN
240 m (800 FT)
210 m (700 FT)
180 m (600 FT)
150 m (500 FT)
120 m (400 FT)
90 m (300 FT)
60 m (200 FT)
30 m (100 FT)
0 m (0 FT)
.15 m (0.5 FT)
.30 m (1.0 FT)
.45 m (1.5 FT)
.60 m (2.0 FT)
.75 m (2.5 FT)
.90 m (3.0 FT)
$\Delta D = (D_{um} + C_t - D_b)\left(\frac{S}{S_r}\right)^2$



$$\Delta D = (D_{um} + C_t - D_b)\left(\frac{S}{S_r}\right)^2$$



$$\Delta D = (D_{um} + C_t - D_b)\left(\frac{S}{S_r}\right)^2$$

APPENDIX E
CONDUCTOR DATA REQUEST FORMS

This appendix provides typical request forms for obtaining conductor sag-tension data and conductor vibration design data from conductor manufacturers or qualified consultants. The information to be provided in the request is discussed in Part IV of this design manual.

If not certain as to design needed, it is recommended that the manufacturer or consultant be contacted before requesting data.

REQUEST FOR CONDUCTOR SAG-TENSION DESIGN DATA

Requested By ______________________________ Date ____________

Utility/Consultant ______________________________

Address ______________________________

Fill in the request blanks with appropriate information or indicate not required. Indicate units of measurements used. For tension give value or indicate percent of breaking strength.

1. Conductor Size, Stranding, Type, Code Name if Known: ______________________________
2. Design Loading, Indicate NESC Light, Medium, Heavy; or Special: ______________________________
   If Special, Provide Loadings: Wind ____________ Ice ____________
3. Design Loading Tension Limit: ______________________________
4. Other Tension Limits: Identify and Give Values. ______________________________
   ____
   ____
5. List Ruling Spans Needed: ______________________________
6. Temperature Range Needed for Stringing Sag Data: ______________________________
7. Maximum Operating Temperature: ______________________________
8. Minimum Temperature for Uplift: ______________________________
9. Extreme Wind Force or Velocity: ______________________________
10. Extreme Ice Thickness: ______________________________
11. Other Sag-Tension Data, Cross Out or Add as Needed.

    15°C (60°F), bare wire, no wind, final sag.
    15°C (60°F), bare wire, 290 Pa (6 lb/ft^2) wind, final sag.
    15°C (60°F), bare wire, 190 Pa (4 lb/ft^2) wind, final sag.
    50°C (120°F), bare wire, no wind, final sag.
    0°C (32°F), NESC ice coating for loading district, no wind, final

12. Comments: ______________________________

____

REQUEST FOR CONDUCTOR VIBRATION DESIGN INFORMATION

Requested By ______________________ Date ______________

Utility/Consultant ______________________
(name & address) ______________________

Name, Location and ______________________
Voltage of Line ______________________

For each design ruling span and conductor size, provide the following information: (*essential information)

1. Conductor Size, Stranding & Type* ______________________

2. Associated Phase or Neutral Size & Type ______________________

3. Avg. Annual Min. Temperature (AAMT) for Line Location* ______________

4. Design Ruling Span* ______________ 5. Maximum Design Tension ______________

6. Wind Loading ______________ 7. Ice Loading ______________

8. Initial Tension (bare wire) at AAMT* ______________________

9. Final Tension (bare wire) at 15°C (60°F)* ______________________
or Avg. Annual Temp. (AAT)

10. Maximum Steady Wind Velocity* ______________________

11. Maximum Span ______________ 12. Minimum Span ______________

13. Armor Rods (yes or no) ______________ Catalog No. if Known ______________

14. Type Attachment (tie wire, clamp, etc.) ______________________

15. Terrain Features (flat, rolling, mountains). Specify all lake or major river crossings if known. Also provide comments on vegetation in area if information available. ______________________

____

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____

16. Comments ______________________

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*U.S. GOVERNMENT PRINTING OFFICE : 1982 O- 522-013/4061